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ABSTRACT

Abstracts of most of the papers, symposia, and poster sessions presented at the 60th conference of the National Association for Research in Science Teaching (NARST) are provided. Subject areas addressed include: videodisc technology; problem solving; cognitive learning; attitudes toward science; teaching strategies; science, technology, society; learning in informal settings; science process skills; gender differences; teaching with microcomputers; textbooks and instructional materials; information processing; wait time and questioning techniques; teacher concerns; science curriculum; teacher education; misconceptions in science; philosophy of science; and cross-cultural research. (ML)

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Washington, DC
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PREFACE

The SMEAC Information Reference Center for Science, Mathematics and Environmental Education has cooperated with the National Association for Research in Science Teaching to provide abstracts of most of the papers presented at the 60th annual conference in Washington, D.C., April 23-25, 1987.

All persons who had papers or symposia accepted were invited to submit abstracts for inclusion in this publication. Some editing was done by the ERIC staff to provide a general format for the abstracts. Special recognition should be given to Dr. Linda DeTure and the NARST Program Committee who obtained the abstracts and organized the program.

Everyone presenting a paper at this conference is encouraged to submit to the ERIC Clearinghouse for Science, Mathematics, and Environmental Education a copy of their paper to be considered for inclusion in the ERIC data base. A submission form is included on page iii of this publication. Papers which are not submitted cannot be included in ERIC.

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Patricia E. Blosser
Stanley L. Helgeson
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Session A-1

KNOWLEDGE AND SKILLS OF SCIENCE TEACHERS: PERSPECTIVES FROM FOUR RESEARCH PROGRAMS

Peter W. Hewson
University of Wisconsin-Madison
Madison, WI 53706

Elizabeth G. Cohen
Stanford University
Stanford, CA 94305

Julie P. Sanford
University of Maryland
College Park, MD 20742

Donna Sabers
University of Arizona
Tucson, AZ 85721

This symposium brings together researchers with four different perspectives on the question of what knowledge and skills science teachers need. Results of research in science education are often discussed in terms of what constitutes effective practice, what science teachers should do. Participants in this session go one step beyond the effective practice question to consider what findings of their research suggest about the categories of knowledge and skills science teachers need.

Four current, diverse programs of research are represented. First, studies of physics learning at the University of Wisconsin suggest that teachers need understanding of conceptual change processes and of students as learners. Second, the Program for Complex Instruction at Stanford University has implications about necessary teacher understanding of classroom processes, group dynamics and status problems. Third, study of academic work in science classroom and teacher planning highlights teacher knowledge of curriculum goals, science content and classroom processes and pressures. Finally, a discussion of The Expert Pedagogue Study at the University of Arizona focuses on pedagogic knowledge and cognitive characteristics of expert science teachers.

THE USE OF VIDEO-BASED TECHNOLOGY TO DEVELOP CONTEXTUALLY RICH INSTRUCTION IN SCIENCE

Robert D. Sherwood
Peabody College of Vanderbilt University
Nashville, TN 37203

The primary goal of this research was to investigate the coupling of videodisc technology with theories of learning and instruction in order to help students learn more effectively in science. The work is based upon the development of idealized learning environments similar to those used by students in everyday situations.

The subjects of the study were sixth grade students of various achievement levels in an inner-city middle school. The treatments involved the use of three different methods. Treatment one made use of video based instruction using segments of the film Raiders of the Lost Ark plus textual material and an active teacher mediation model. Treatment two used video plus textual materials without active teacher mediation. Treatment three used only textual materials. The areas of direct science instruction involved the areas of density and knowledge about spiders.

Outcome measures included written questions about the two areas of science instruction as well as a transfer task where students were asked to indicate how various science ideas might be used by an explorer preparing for a trip.

Results indicated a significant difference for students involved in the video plus text plus teacher mediation method for the spiders science information. No difference was found for the density information. The transfer task results also favored the first treatment.

The results indicate that adding a video component, coupled with teacher mediation that draws attention to the important points of the video, may be effective in certain science learning situations.

THE INFLUENCE OF INTERACTIVE VIDEODISC SIMULATIONS ON STUDENT ACHIEVEMENT IN AN INTRODUCTORY COLLEGE CHEMISTRY COURSE

Michael L. Waugh
University of Illinois
Champaign, IL 61820

The purpose of this research was to examine the influence of selected interactive videodisc (IVD) laboratory simulations on the achievement of first year college chemistry students. A series of IVD laboratory simulations were developed which combined microcomputer graphics and text with video images from a laser disc player. These simulations consisted of tutorial segments and experimental activities which are lightly branched, allow for variation in student input, and provide immediate feedback to the student.

These IVD laboratory simulations were examined as both enhancement and substitute for traditional laboratory activities. A group of 103 introductory chemistry students in five laboratory sections was randomly assigned to one of three treatments. One of the groups experienced a traditional laboratory on the topic of chemical equilibrium while a second group experienced a series of short IVD laboratory simulations on the same topic and the third group received first the IVD laboratory simulations and then the traditional laboratory experience.

Student laboratory reports and quiz scores on the topic of equilibrium were employed as measures of achievement. On both of these measures, students who experienced the IVD laboratory simulations scored significantly better ($p < .01$) than those who experienced the traditional laboratory.

A COMPARISON OF STUDENT PERFORMANCE BY INTERACTIVE VIDEODISC VERSUS CONVENTIONAL LABORATORY

William H. Leonard
Clemson University
Clemson, SC 29634

This experimental study was designed to learn if students perceived an interactive computer/videodisc learning system to represent a viable alternative to (or extension of) the conventional laboratory for learning biology skills and concepts normally taught under classroom laboratory conditions. Data were collected at a large midwestern university where students were randomly assigned to an interactive videodisc/computer lesson on respiration and biogeography or a traditional laboratory investigation teaching the same concepts. The system consisted of a TRS-80 Model III microcomputer interfaced to a Pioneer laser disc player and a color TV monitor. Results show no statistically significant differences between the two approaches for student grades on laboratory quizzes, laboratory reports, a laboratory final exam, and the course grade. It is inferred that the videodisc/computer technology will not necessarily serve as a viable substitute to the "wet" laboratory experience, but that this medium may provide a substitute for some conventional laboratory exercises and may enrich the spectrum of educational experiences usually not possible in typical classroom settings.

Session A-3

KNOWLEDGE ORGANIZATION AND REPRESENTATION IN SOLVING PHYSICS PROBLEMS

George J. Pallrand
Rutgers - The State University of New Jersey
New Brunswick, NJ 08903

A series of problems in kinematics of increasing difficulty was used to investigate the manner in which subjects use and represent knowledge in solving problems. Knowledge previously obtained is at issue, as is knowledge presented and acquired during the problem-solving episode. Questions relating to the nature of the knowledge sought as well as to its intended use were also at issue. The use of feedback in the problem situation was also considered as was the role of internal representation and knowledge organization as they relate to performance.

This research used computer simulation to present the problem and permit the subject to interact directly with aspects of the problem environment. This approach provides a number of advantages which include the use of graphics and immediate feedback. Equations and formalisms were not required since relationships can be expressed graphically.

Forty precollege science and mathematics teachers served as subjects. Each subject was presented with the problem of describing the path of projectiles shot from a cliff. The subject was asked to draw the path on paper. This response was then checked with the computer simulation. This technique provided a mechanism for adding knowledge as the interview progressed. Interviews followed a structured protocol. Taped interviews together with the drawings provided the unit of analysis for each subject.

Subjects were able to isolate variables in generating pictorial representations but were unable to coordinate variables consistently. They also experienced difficulties in altering their frames of reference and in using acquired knowledge in new situations. The remaining individuals were able to isolate and coordinate variables when the motion of a single projectile was being examined. When the motion of two objects was at issue, they experienced varying degrees of success. Individuals functioning at higher cognitive levels demonstrated greater degrees of success in solving the motion problems.

Those experiencing difficulties representing the motion of the object were those who used knowledge in more limited ways. The knowledge they sought was more piecemeal and random. Their responses were local and appeared unrelated to any general pattern. The responses of the more cognitively able individuals were referenced across a number of situations. They also appeared to use feedback to advantage and the information sought appeared related to some hypothesis in question.

The manner in which knowledge was represented appeared to be related to the manner in which knowledge was organized and used. These findings cast doubt on aspects of the misconceptions of science literature. Misconceptions in science may be inappropriately labeled. Individuals express what appear to be misconceptions because they lack the cognitive abilities to represent the phenomena.

A PROCESSING APPROACH TO KNOWLEDGE ORGANIZATION

Alan W. Naimoli
Rutgers Graduate School of Education
New Brunswick, NJ 08903

Twenty graduate students who were practicing teachers taking a graduate level course related to teaching mathematics and science 7-12 served as subjects. Protocols were collected using a computer simulation of force and motion problems divided into successive phases. Variables included the initial position of a projectile, velocity, angles and force due to gravity. In the first phase, the subjects manipulated the velocity of the projectile. In the second phase, velocity and initial direction could be controlled and in the third phase all the variables could be manipulated.

The essential knowledge needed to solve the problems was provided to each subject in the form of assumptions at the beginning of the simulation. Three groups of problem solvers were identified.

The first group made predictions that seemed unrelated to knowledge they had presumably acquired at a previous level. This group was able to solve only the initial phase of the problem set. Their protocols demonstrated a "generate and recognize" method of information recall. The proximity of the information needed to make a successful prediction was a major factor for this first group.

The second group was able to solve the first and second phases of the problem set. They were able to recognize relationships and imply a more heuristic method of problem solving. Their knowledge representations tended to be linked as route knowledge consisting of a sequence of steps leading to a prediction. Velocities close together, for example, were sequenced while more remote velocities were not.

The third group of subjects was able to solve the first and second phase as well as some parts of the third phase of the problem set. These subjects organized sequences into more global relationships characteristic of survey knowledge. When faced with a novel problem that seemed related, they evaluated the similarity between the novel and familiar problem and used the familiar problem to make predictions about the novel one.

Learning by rote is evident in a majority of today's science classrooms. Once the component parts of a concept are known, it is assumed that the concept has been learned. When called upon to relate such concepts to novel problem solving situations, the learner is ill-served.

The ability to think "productively" depends on chunking knowledge into schema which can be assimilated through instantiation, integration and semantic elaboration. Emphasis in science teaching must be placed on these latter categories rather than on the compartmentalization of knowledge.

MENTAL MODELS IN QUALITATIVE REPRESENTATION

Daulat N. Husain
Rutgers - The State University of New Jersey
New Brunswick, NJ 08903

Teaching usually involves transference of large amounts of knowledge in the form of information from the teacher to the student. The selection of topics to be learned and concepts to be mastered have become a dilemma, and there is growing realization that there has to be a shift in emphasis from what is learned to how it is learned. If the cognitive processes of learners could be identified and qualified, the transference of knowledge from the teacher to the learner would be better facilitated and more efficient. Currently, an issue in research on understanding how learning occurs has to do with how individuals choose and work with these processes when confronted with a problem. This paper reports on mental models, if any, that are in use during a problem solving activity.

Forty graduate students served as subjects. They were practicing science/math teachers with general academic backgrounds. Subjects were asked to draw out their predictions for the problems posed. The drawings along with limited probe questions provided the analytical data. Each subject was individually tested and the sessions taped.

Levels of operations were identified, based on which, the performance of the problem solvers in terms of their mental models was inferred. These are extension of the given knowledge; reordering of the held knowledge; integration of the learned knowledge with new variables; reconstruction of the knowledge representation and finally (at the expert level) envisioning all the factors as a coordinate.

Sixty percent of the population carried out the simple operations. Forty percent reached the 4th and 5th stages. Very few subjects successfully solved all of the problems. Algorithmic learning background and interference from experiential knowledge accounted in most instances for a lack of any efficient mental model, and the difficulty that the subjects faced in solving problems in kinematics.

This calls for a closer look at how we learn and how we can teach. Global concepts need to be stressed so that students not only learn rules but also when and how to apply them. With further understanding of the mental processes in operation while problem-solving, a better cognitive fit between the mental model of the teacher and that of the learner would expedite teaching and bring about a more effective form of communication between them.

KNOWLEDGE STRUCTURES IN PROBLEM SOLVING

Frank A. Gagliardi
Rutgers - The State University of New Jersey
New Brunswick, NJ 08903

In problem solving research we are usually interested in the performance and problem-solving behavior of the "expert." The expert problem-solving strategy possess considerable knowledge of the domain and employs a paradigm which generates the circumstance in which knowledge can be observed for its actions and modeled.

Much of the problem solving research has utilized complex problems in areas such as physics. The formalism associated with these types of problems encourages the problem solver to employ an algorithmic solution. This research used a computer simulation to present the problem, and permitted the subject direct access to interact with the variables of the problem environment. This approach provided a number of advantages which included the use of graphics to study the subject's representation of knowledge in a problem-solving situation.

The analysis of the expert's representation supports the view that the most appropriate knowledge applications for solving a problem are implemented through knowledge representations, as knowledge structures. Knowledge structures are represented as procedures, sets of rules, or logic assertions and are the only means by which knowledge representations can be modified. Increasing attention needs to be given to the processes by which knowledge is represented and modified. This attention lends itself to the development of a problem-solving model that could be used to gain insight into the non-expert problem solver's performance and to develop a model for learning, to optimize the problem solving proces.

INTERACTION OF CURIOSITY AND VERBAL FLUENCY WITH LEARNING BIOLOGIC CONCEPTS PRESENTED INDUCTIVELY AND DEDUCTIVELY

John J. Koran, Jr.
Mary Lou Koran
John S. Foster
University of Florida
Gainesville, FL 32611

In a study designed to explore the relationship between curiosity, verbal fluency, grade level and learning science from inductive and deductive modes of presentation, 123 seventh and eighth grade students were randomly assigned to three groups. Each group was administered aptitude tests for curiosity and verbal fluency and subsequently one of the following treatments: (1) deductive instruction; (2) inductive instruction; or (3) control. All subjects participated in the study early in the semester when they had not experienced the biologic content of the treatments (species diversity).

The study took place over a period of four days using a post-test only control group design with sample mortality reducing the final sample analyzed to 81 Ss. Multiple regression analysis indicated that there were significant interactions between grade x treatment, $p < .05$; and grade x vocabulary x treatment $p < .05$. For eighth graders, treatments 1 and 2 significantly exceeded the control. For seventh graders treatment 1 exceeded treatment 2 and the control. Overall, students scoring high on verbal fluency scored better in all groups regardless of grade level. Curiosity did not interact significantly with the treatments under either condition although there were significant correlations between psychomotor curiosity and the written measure of curiosity used; and written curiosity and vocabulary.

ELABORATIONS: DIFFERENCES IN METACOGNITIVE BEHAVIOR OF SUCCESSFUL AND LESS SUCCESSFUL SCIENCE STUDENTS IN TRINIDAD

Lucy Durgadeen
Ministry of Education, Trinidad and Tobago
Trinidad, West Indies

Elaboration is the manner in which learners embellish and encode knowledge. Researchers have noted that elaboration leads to deeper processing and consequently facilitates learning and enhances memory. However, elaborations per se are not necessarily facilitative. For elaborations to be effective, they must be precise and must represent a non-arbitrary association between the to-be-learned material and the learner's prior knowledge.

The purpose of this study was to assess the effect of precise and imprecise elaborations on the science learnings of successful and unsuccessful secondary science students in Trinidad.

The participants in this study were 88 second year science students at a five-year secondary school in Trinidad. Scores on teacher-made tests were used to rank all students. The sample size of subjects for the three-phased study was 44 successful and 44 less successful students.

In Phase I the questions asked were: Do successful students generate more precise elaborations than do less successful students? Do students learn and remember precise elaborations better than unelaborated or imprecise elaborations? The results: Given base sentences, successful students generated more precise elaborations than did less successful students. The correlation of precision of elaboration and recall scores supports the hypotheses that precise elaborations are related to memory performance.

In Phase II the question asked was: Do students learn and remember precise elaborations better than unelaborated sentences or imprecise elaborations? The results: Relevant instructions facilitated recall which was significantly higher from precise elaborations than from both base sentences and imprecise elaborations.

In Phase III the question asked was: Do successful students have better metacognition about precise elaborations as an aid to learning than less successful students? The results: Analysis of the data showed no significant differences between students in the two groups.

In science, students should use precise elaborations as they engage in such science processes as observing and inferring. Elaborations seem to be important when science students identify relationships and use models and analogies to acquire concepts and principles.

EFFECT OF VERBAL AND VISUAL MODES OF PRESENTATION ON CHILDREN'S RETENTION OF IMAGES AND WORDS

Ann C. Howe
Ellen Vasu
North Carolina State University
Raleigh, NC 27695

This study tested the hypothesis that the use of two modes in presentation of scientific information has an additive memory effect for both images and words. Subjects were 25 first grade children and 22 fourth grade children randomly assigned to Perceptual-Verbal (PV) and Perceptual (P) groups. The PV group heard a description while looking at a cut Kiwi fruit; the P group observed the same fruit but did not hear a description. Children were tested individually immediately after presentation of stimuli and two weeks later by instructions to represent the information recalled in both verbal and pictorial form. In general, results supported the hypothesis and indicated, in addition, that children represent more information in iconic (pictorial) form than in symbolic (verbal) form. Strategies for using these results to enhance science learning at the elementary school level will be discussed.

EFFECTS OF ANALOGY INDUCED SCHEMA IN NEW DOMAIN LEARNING

Kenneth German
Donald W. McCurdy
University of Nebraska
Lincoln, NE 68588

The purpose of this experiment was to study the effect of using a highly automatic, but not deeply understood, personal skill (decimal counting) as an analogy (advance organizer) for learning to count in other number systems. An experimental group received material designed to provide such a sensitization. Their subsequent actions in using the instructional program were studied and compared with subjects (control group) who did not receive the sensitizing analogy material until after the instruction was completed. A computer instruction program was written to be used as a vehicle for presenting the material to a group of college students.

The program was constructed in a series of modules which was presented to a group of college students in a basic computer science course during the spring of 1986. The findings support the hypothesis that subjects receiving an analogy to enable understanding of an abstract advance organizer achieved richer and longer lasting learning. This conclusion is based on three achievement measures and on the analysis of the learning sessions. Although few of the measures were statistically significant in themselves, the number of indications adds substantial support. In addition, the effect sizes were consistent with those reported in several meta-analyses of advance organizer research.

THE RELATIONSHIP BETWEEN ATTITUDE TOWARD SCIENCE, SCIENCE SELF-CONCEPT AND SEVERAL VARIABLES OF OCCUPATIONAL CHOICE TO THE SCIENCE CAREER OF BLACK COLLEGE STUDENTS

Charles Robert Salters
Morgan State University
Baltimore, MD 21239

J. David Lockard
University of Maryland, College Park
College Park, MD 20742

The purpose of this study was to determine the relationship between the Black college student's attitude toward science, science self-concept, and other variables of occupational choice and the selection of an academic major. A secondary purpose was to determine the combined effect of the variables of occupational choice on the selection of an academic major.

The sample for the study consisted of 410 science and non-science majors at Morgan State University, Baltimore, Maryland.

The Purdue Masters Attitude Scale, Brookover's science self-concept of ability scale, and a questionnaire developed by the principal researcher were used to collect the data, test the hypothesis, and answer the research questions.

The results revealed that selection of major was related to 10 of the 12 variables investigated. Multiple regression analysis revealed that only 6 of the variables could be identified as making a contribution of greater than one percent. These variables were: (1) science self-concept, (2) presence of role model, (3) image of the field, (4) course counseling, (5) attitude toward science, and (6) high school science background.

Detailed analysis of the multiple regression results revealed that science self-concept explained 21% of the variance in science as a major. Role model explained another 11% of the variance for a total of 32%. These two plus the four additional variables met the criterion of a sizeable contribution. Collectively, these six variables accounted for 42% of the variance.

STUDENT ATTITUDES TOWARD SCIENCE AND SCIENCE-RELATED CAREERS: AN INVESTIGATION OF THE EFFICACY OF A HIGH SCHOOL BIOLOGY TEACHER'S INTERVENTION PROGRAM

Cheryl L. Mason
Purdue University
W. Lafayette, IN 47907

Jane Butler Kahle
University of Northern Colorado
Greeley, CO 80639

Despite the recent renewed interest in science, a majority of capable students, particularly girls, have not elected to pursue a career in science or even to strive for literacy in science. There is a need to emphasize the usefulness of science in future professional and non-professional work in order to nurture the underdeveloped national resource of women knowledgeable about scientific, technological, and engineering fields.

Specifically, this project sought ways to ensure that girls attain full and fair participation in educational programs in science by removing obstacles, both perceived and actual. In order to modify existing classroom techniques and environments, a Teacher Intervention Program was designed. During a workshop, and through periodic personal communications, teachers were sensitized to the necessity of providing a stimulating gender-free learning environment. In addition, they were presented with a variety of methods and materials which have been shown to encourage students, especially females, in science.

The random sample of twelve teachers represented a wide variety of classroom and socio-economic environments. Therefore, it was assumed that the student subjects could be taken to be representative of the general populace of science students, at least in the central United States. The subjects tested were students in 24 biology classes taught by 12 secondary school teachers.

In order to test the effectiveness of the Teacher Intervention Program, both qualitative and quantitative measures were employed. Using two-way ANOVA's, treatment group by student sex, a comparison of the mean scores was made for all students, for all females, and for all males. The results indicated that the experimental group, compared to the control group, had significantly higher mean scores on tests of attitudes, perceptions, extracurricular science activities and interest in a science-related career. In order to assess behavioral changes, additional information about students and teachers was secured through qualitative methodologies, such as interviews and observations.

GENDER INEQUITY CYCLE - THE MATH CONNECTION

James R. Campbell
Francine Mandel
St. John's University
Jamaica, NY 11439

Jeanne Pizzo
N.Y. Public Schools, Dist. 24
New York, NY

We have isolated an inequity cycle that helps explain why females and certain minorities avoid careers in the technical areas (engineering, science and mathematics). The cycle starts with parents exerting different influences on males and females all through their developmental years. These social-psychological forces are reinforced by elementary school teachers and peers; causing males to develop stronger math and science academic self-concepts.

These self-concepts foster heightened interest in mathematics and especially in the sciences and result in the development of a technical orientation (between grades 4 and 7). Such an orientation leads to the enrollment in advanced technical courses at the high school level. By pursuing the more rigorous courses at the high school level such students achieve higher scholastic aptitude scores (especially SAT-M) which qualify them for the more prestigious technical colleges. Once they are admitted to such colleges they tend to major in the technical careers and go on to become scientists, engineers or mathematicians. The cycle is repeated when these individuals become parents and provide the same socio-psychological forces to their offspring.

This study attempted to isolate specific socio-psychological forces (parental pressure, parental assertiveness, psychological support, parental monitoring) that parents exerted on 437 elementary students enrolled in gifted programs and 364 "average" students. We used path analysis (PLS Path) with mathematics achievement (Stanford Diagnostic Math Test) as the dependent variable and gender, enrollment in gifted program, ethnicity, father's education, mother's education, and the four parental factors as predictor variables.

The results of this study do show that parents reinforce the socializing efforts of peers and elementary school teachers. We are not certain where these forces begin but it is clear that peers, teachers and parents all socialize the children--especially girls, in the same direction. Gifted Caucasian females are particularly affected by such influences and these forces seem to orient them away from the technical areas. Furthermore, the study shows Caucasion females to be influenced differently from the Asian-American females and from the high achieving male groups. These differences are then compounded in their further education (junior high school, high school and college). The net effect of such differences could produce the gender inequities that we find in the technical areas. All of these data lead us to conclude that our gender inequity cycle is an accurate conception of this problem.

Session A-6

THE EFFECTS OF HANDS-ON AND TEACHER DEMONSTRATION LABORATORY METHODS ON SCIENCE ACHIEVEMENT IN RELATION TO REASONING ABILITY AND PRIOR KNOWLEDGE

George E. Glasson
Indiana University
Bloomington, IN 47405

The present study compared the relative effects of hands-on and teacher demonstration laboratory methods on declarative knowledge (conceptual) and procedural knowledge (problem-solving) achievement. Of particular interest were (a) whether these relationships vary as a function of reasoning ability, and (b) whether prior knowledge and reasoning ability predict student achievement.

Ninth grade physical science students were randomly assigned to classes taught by either a hands-on or teacher demonstration laboratory method. Students' reasoning ability and prior knowledge of science were assessed prior to the instruction.

The instructional treatments resulted in equal declarative knowledge achievement. However, students in the hands-on laboratory class performed significantly better on the procedural knowledge test than did students in the teacher demonstration class. These results were unrelated to reasoning ability.

These findings support the results of past research that students perform equally well on declarative knowledge tests in classes taught by hands-on and by teacher demonstration laboratory methods. Procedural knowledge gains have been previously demonstrated only with formal operational students after they have constructed three-dimensional models of molecules. The present study indicates that all students, regardless of reasoning ability, showed procedural knowledge gains after exposure to a hands-on laboratory method. It was concluded that the ability to solve problems is enhanced if students have applied reasoning strategies in the process of actively performing an experiment.

Prior knowledge significantly predicted performance on the declarative knowledge test. Both reasoning ability and prior knowledge significantly predicted performance on the procedural knowledge test, with reasoning ability being the stronger predictor.

STUDENT REACTIONS AND FEELINGS TOWARD TESTING AND TEST FEEDBACK IN AN INTRODUCTORY BIOLOGY COURSE

D. Daryl Adams
University of Georgia
Athens, GA 30602

Sixty-three elementary education undergraduate students (primarily female) in four introductory biology classes were surveyed to determine their feelings and reactions towards tests and testing. A 24 item Likert-type instrument was developed and administered during the first few days of the academic quarter. After collecting baseline data, two classes were designated experimental and two, control. The experimental classes were subjected to test-grading procedures that gave only positive comments while the control students encountered the normal "mark the incorrect response" policy. The experimental treatment lasted ten weeks and ended with all the subjects responding to the instrument for a second time as a post measure.

Baseline data from the students showed no significant differences between experimental and control groups. The data indicated that the students do not like to take tests and seldom thought getting them back was a negative experience. They also liked to find out how much they knew on a test and did care about the correct answer to items they missed.

The students said they always read over the questions they missed and sometimes read over the ones they got right. They also thought they learned from taking a test and were motivated to do better on the next test regardless of the grade received.

Students thought the function of a test was to find out what they knew and they said that they would feel better about the test if more attention was given to the items they missed.

A significant difference ($p<0.05$) was found on two items after the treatment. The experimental group felt that getting back a test was a less negative experience than did the control group. The experimental group also missed the usual attention given to the missed items.

THE EFFECT OF VARIED STRATEGIES TRAINING ON CLASSROOM LESSON PLANNING SKILLS

Virginia Carol Demchik
Jefferson County Schools
Shepherdstown, WV 25443

Dennis W. Sunal
West Virginia University
Morgantown, WV 26506

The purpose of this study was to determine the effect of intensive instruction and the interacting variables, cognitive function and science experience, on lesson plan development and evaluation.

Thirty-eight (38) senior level elementary education students enrolled in a methods course (Spring, 1986) participated in the study. Formal or non-formal cognitive level was established by the GALT test. Random sampling was used to assign students to the treatment or control groups. Two classes with identical objectives were taught by two instructors. The only difference was that the treatment group received intensive instruction training.

The subjects developed a lesson plan and evaluated a lesson plan in the pretreatment and the posttreatment phases. Lesson plan scores, number of comments, and the quality of comment scores were used as the dependent variables in analysis. The independent variables were treatment, cognitive function, and science experience. The treatment group received instruction in cue attendance, information search, and hypothesis generation while the control group received an equally difficult task.

The data were assessed by both multivariate analysis of variance (MANOVA) and simple analysis of variance (ANOVA) to determine the effect of independent variables of treatment, cognitive function, and science experience. It was concluded that intensive instruction training is a powerful instructional strategy that results in higher scores on lesson planning and lesson plan evaluation. The level of cognitive function and science experience aided in the results. The main effect of the study showed that students who received intensive instruction with cognitive function or science experience as interacting variables were able to write significantly better lesson plans than was the control group.

There was a significant main effect for lesson planning with subjects in the treatment-non-formal group scoring higher than any other group. There was also a significant main effect for students of higher cognitive function and high science experience than for any other group. There was no significant main effect between treatment and science experience.

However, subjects who received intensive instruction, with the interacting variables, showed a significant difference in the quality of comments made but not in the number of comments during the evaluation of the lesson plan when compared to the control group.

Session A-7

CONTENT ANALYSIS OF SCIENCE TEXT

Ron Good
Louisiana State University
Baton Rouge, LA 70803

O. Roger Anderson and Steven Botticelli
Columbia University
New York, NY 10027

Bonnie Armbruster
University of Illinois
Champaign, IL 61820

Robert Evans
Wake Forest University
Winston Salem, NC 27106

Larry Yore
University of Victoria
British Columbia, V8W 24Z Canada

The purpose of this symposium is to focus attention on the need to improve science textbooks by building a comprehensive model of low- and high-inference science text analysis. Analysis of science textbooks and related instructional materials, using low-inference criteria, results in data that can be combined with high-inference evaluations to provide more accurate, reliable indicators of the nature of science textbooks. The results can then be used by developers of textbooks to improve them and by those who select them to ensure the highest possible quality.

The participants in this symposium will present the results of research on quantitative analysis of science textbooks and related instructional materials. One analysis scheme assesses the continuity of thought and the distribution of shifts in emphasis of content. The scheme is applied across and within science texts to determine the relative contribution of implicit and explicit levels of structure to the organization of the content.

Another analysis scheme uses recent theory and research in reading comprehension. Three major characteristics of considerate text are: (1) structure/organization, (2) coherence, and (3) audience appropriateness. Implications of this research are directed toward publishers and textbook adoption committees.

A third emphasis in the symposium includes evaluation instruments developed to analyze instructional materials that accompany student science textbooks. The instruments assess the use of process skills, inquiry experience, and problem-solving activities.

In addition to schemes for analysis, teachers' intents and uses of textbooks will be a part of the research presented in this symposium. This naturalistic research can provide data for formulating more precise research questions and hypotheses about science-reading issues.

Session A-8

AN ETHNOGRAPHIC STUDY OF CURRICULAR CHANGE: HIGH SCHOOL CHEMISTRY WITH AN APPLIED AND SOCIETAL ORIENTATION

Ronald D. Anderson
University of Colorado
Boulder, CO 80309

A new high school chemistry course, Chemistry in the Community or CHEMCOM, prepared by the American Chemical Society with financial support from the National Science Foundation, was pilot tested during the 1985-86 academic year with 62 teachers clustered in several test centers across the country. This paper reports a case study of teachers' responses to it -- a representation of the course and its role in schools as seen through their eyes.

Given that many innovative curricular programs of the last two or three decades have not persisted in the schools, at least in the form intended, there is reason to think that a better understanding of the culture for which a new course is being prepared could be of substantial benefit.

The methodology used in this study could be described as ethnographic interviewing. In contrast to the typical social science modes of investigation, this approach does not impose a conceptual framework through which the investigator intends to describe the situation. Instead, this approach lets such conceptualizations emerge from the people involved; it is basically an examination of their culture, expressed as much as possible in their own language.

At the core of the resulting description is a cultural contradiction -- an unresolved question as to what high school science education is intended to accomplish. As is common to many cultural contradictions, teachers are often unaware of its presence, but nevertheless its presence is real.

All else that teachers said about what students need, should have, or get from the study of chemistry pales beside their concern for preparing the college-bound students to study more chemistry when they get to college. There is an unresolved tension which teachers feel between their perceived need to prepare college-bound students to succeed in college and their desire to present chemistry in a way that has relevance for other aspects of their students' experience, such as being intelligent voters and making use of chemistry principles in their daily life.

In addition to this issue, other related matters are involved, such as teachers' concerns about the teaching methodology required and the strong component of social studies which CHEMCOM is perceived as having.

One possible outcome of the cultural contradiction described above is that objectives other than the traditional ones could be neglected. Another possible outcome is an out-and-out rejection of the CHEMCOM course by some teachers. Yet another result could be the disappearance of the new teaching approaches, e.g. role playing, simulations, and work in small groups, if teachers do not resolve the contradiction.

Another possible outcome -- a quite positive outcome -- is that the presence of CHEMCOM will fuel the debate about goals of science teaching and contribute to the resolution of the contradiction within the culture of the community of science teachers.

FIVE CRITICAL FACTORS TO CONSIDER IN THE DEVELOPMENT AND IMPLEMENTATION OF A SCIENCE-TECHNOLOGY-SOCIETY CURRICULUM FROM THE PERSPECTIVE OF SELECTED JUNIOR HIGH SCHOOL SCIENCE TEACHERS

Carole P. Mitchener
University of Missouri - St. Louis
St. Louis, MO 63121

The goal of developing scientific literacy in all students is important if the drive toward a society of responsible, decision-making citizens is to be sustained. Science-technology-society curricula are a means of reaching a greater student population with a broad array of science-related content and understandings.

While science-technology-society curriculum models encourage the development of scientific literacy in all students, and while there is much STS curriculum development being done nationally, there is a void of information on how these STS curricula are being accepted and implemented by teachers. This study begins to fill that void by examining the implementation of a junior high school STS curriculum, cited as an exemplary model by the National Scence Teachers Association in 1982.

There were two purposes of the study: (1) to examine teachers' beliefs and value systems which influenced their perceptions of this STS model curriculum, and (2) to report the factors that the teachers perceived to be critical in the development and implementation of this STS curriculum, factors which influenced their decisions to accept, alter, or reject the course.

The methodology was qualitative and made use of a case study format to examine the implementation of the curriculum. A triangulation method of data collection was used: (1) recorded observations of science classes, (2) clinical interviews of science teachers, and (3) analysis of relevant documents.

The teacher population was divided into three groups: those who accepted, those who altered, and those who rejected the curriculum. When comparing these three groups, the results showed five critical factors of this science-technology-society model curriculum which were common to all three groups. These five critical factors which warrant consideration in the development and implementation of STS integrated curricula are as follows: (1) concerns over content, (2) frustrations about student population, (3) uncertainties about evaluation, (4) discomfort with grouping, and (5) confusion over teacher role.

Teachers' perceptions of a new curriculum are crucial to its acceptance or rejection. More attention needs to be given to those factors the science teachers perceive to be critical in the development and implementation of science curricula. If the goal of promoting more scientifically literate students is to be more fully realized, the teachers' perceptions of the new STS curricula must be further investigated and understood.

GLOBAL SCIENCE, AN STS CURRICULUM: A NATURALISTIC PERSPECTIVE

MaryAnn Varanka
Estes Park High School
Estes Park, CO 80517

Naturalistic research methods were used to examine the elements of Global Science: Energy, Resources, Environment (GS), a science/technology/society (STS) secondary school curriculum by John Christensen, that have led to the choice and use of the program by four Colorado teachers. Classroom observations, individual teacher interviews, small group student interviews, and teacher workshop observations were conducted with the subjects and their students. Classroom observations included GS classes as well as the other subjects taught by the teachers. The four teachers represented three school types (rural, urban, and suburban) in three districts or different demographic characteristics. The teachers also represented a range of teaching experience, both using the GS program and in general.

Five considerations underlie the choice and use of GS by the observed teachers.

1. GS is a textbook-based curriculum with a laboratory manual and teacher's guide available.

2. The teaching format used in GS is not radically different from the pedagogy of traditional science courses.

3. The integrations of the technological and societial issues has been pre-planned by the author and incorporated into the text. It is used in part or *in toto* or supplemented as desired by the teacher.

4. GS uses traditional science skills and teaches identifiable science disciplines.

5. The teachers perceive GS to provide sufficient latitude to allow them to place a personal stamp on the program.

While the sample may not mirror the whole teaching profession as it relates to the teaching of STS curricula in general or to GS in particular, the results provide some insight into teacher reactions to and expectations of one set of STS materials, and possible direction for the development and use of STS curricula nationwide.

It appears that if teachers in general are textbook-bound and if appropriate STS textbooks are nationally available, STS concepts will be taught along with academic preparedness, especially if a major change in pedagogy is not required. An additional requirement for such STS materials is that the materials provide the latitude, perceived or real, for individualization on the part of the teacher.

Session A-9

QUALITATIVE CHEMICAL EQUILIBRIUM PROBLEM SOLVING: COLLEGE STUDENT CONCEPTIONS

Gregory L. Crosby
The University of Maryland
College Park, MD 20742

This study documents the detailed effects of introductory college chemistry instruction on qualitative student equilibrium problem solving ability. Revealed errors and misconceptions provide more prescriptive information for improving current equilibrium problem solving instruction.

Following equilibrium instruction, 20 students solved two qualitative homogeneous equilibrium problems while thinking aloud in an interview setting. One problem was presented ambiguously (unconstrained task-environment) and the other unambiguously (constrained task-environment). Five chemistry professors solved the same problems, from which an expert model of scientifically acceptable conceptions was constructed. Actual equilibrium instruction was compared to the expert model for accuracy and completeness. Acceptable, unacceptable, and missing student propositions were identified by comparison with the expert model. Student responses were examined for common patterns of unacceptable explanations associated with incorrect final answers.

Results indicate that the three most frequent unacceptable student explanations accompanying student errors are: (1) the value of the equilibrium constant varies by changes in amounts at constant temperature; (2) the addition of a common ion to an aqueous solution in equilibrium causes the reaction to go to completion; and (3) any kind of pressure increase will cause a shift in the equilibrium of a homogeneous gaseous system at constant temperature. Nearly one quarter of the students obtained right answers for the wrong reasons. Although problem-solving instruction was found to be accurate, the textbook and lecture instruction were inconsistent and incomplete in explaining what concepts apply in solving qualitative problems.

Recommendations for improving student problem solving abilities include: (1) more qualitative problem solving in introductory college chemistry; (2) explicit and consistent textbook and lecture presentations on what, and how to apply concepts; and (3) the application of concepts to a wider variety of qualitative problems. Problems should be written to more readily expose conceptual errors through graded responses and confront common misunderstandings. For example, chemical educators can provide students with correct answers to ambiguously worded, unconstrained problem statements, and ask students to identify the missing, yet necessary information for solving the problems. Unconstrained problems may prove especially effective in establishing the temperature dependence of K_c for solving chemical equilibrium problems. Providing more explicit connections between concepts and problem solutions permits students to efficiently engage in self-corrective procedures for constructing scientifically accepted views of natural phenomena.

THE REAL DIFFICULTY IN LIMITING REAGENT PROBLEMS

Jean Lythcott
University of Wisconsin-Madison
Madison, WI 53706

It has been well documented that high school chemistry students have difficulty in solving problems in stoichiometry. Limiting reagent problems specifically have proven to be extremely difficult. If students are to improve in their problem solving, it is assumed first that it is inefficient and ineffective to teach a method specific to each problem type encountered in high school chemistry, and, second, that sound conceptual knowledge of the domain in which problems are set is a prerequisite for useful problem solving.

This study was based on Reif's theoretical Model of Desired Performance, with particular emphasis on the components of qualitative redescription, and planning using general heuristics. The question of interest was whether or not students would become more successful problem solvers when they solve using these components of the model. The conceptual knowledge of the students was probed in a recorded interview.

Two classes of high school students had different instruction in the solving of mass-mass problems only, and they were subsequently tested for their ability to solve limiting reagent problems. One class had the usual instruction requiring the use of the factor-label algorithm. The second class had instruction based on the model, when qualitative redescription involved both a macroscopic view of chemical combination as well as a particulate one, and setting subgoals by working backwards were the heuristics of choice. In neither class was the idea of limiting reagent discussed.

After instruction each student was tape-recorded during a problem-solving session, when students used the solving out-loud technique, and each was interviewed about their conceptual knowledge. During the interview students were given an opportunity to solve a limiting reagent problem by answering questions of qualitative redescription posed by the investigator.

Almost half of the students were unable to explain a qualitative, macroscopically described event as one reagent being in excess and therefore remaining unreacted in the reaction vessel. Of those who were able to describe this accurately, four-fifths were from the class that solved according to the model. Further, among this group, a small number showed insight into an appropriate solution path. One solved it correctly. A small number were unable to translate their ideas of proportionality into a mathematical result, while the others had insufficient knowledge of the balanced equation to proceed. Insufficiencies in conceptual knowledge of symbolic language, the mole, and atoms and molecules were abundant. Almost one-fifth of the students described beliefs that gases and/or liquids are not composed of discrete particles. Almost all of the students, however, solved one or both mass-mass problems correctly in the out-loud solving session.

From this preliminary study, with only four days of instruction, it is at least plausible that, when students know more of what a problem is about, their problem solving performance improves. It is claimed that the generation of correct solutions without adequate conceptual knowledge is not useful, and that it is the paucity of conceptual knowledge that is the primary stumbling block to good problem solving in stoichiometry by high school students.

AN ANALYSIS OF PROBLEM SOLVING PROCESSES USED IN COLLEGE CHEMISTRY QUANTITATIVE EQUILIBRIUM PROBLEMS

Barbara A. Gage
Prince George's Community College
Largo, MD 20772

This study investigated and compared the problem solving behavior of college chemistry faculty (experts) and undergraduate chemistry students (novices) in solving three quantitative homogeneous gas phase equilibrium problems. Steps and sequence taken by experts (n=5) and novices (n=20) were compared to a standard general college chemistry textbook presentation or three problem types: (1) computing K_c from equilibrium concentrations of all species; (2) calculating new equilibrium concentrations of species when a product is added to a system at equilibrium; and (3) calculating species equilibrium concentrations starting with amount of one reactant.

Subjects interviewed during solution of the problems were asked to think aloud as they progressed, explaining each step taken. Interviews were tape-recorded and transcribed. Resulting protocols were analyzed to: (1) identify procedural steps taken; (2) record sequence of steps taken; (3) compare expert and novice sequences to textbook model; and (4) identify procedural and conceptual errors made by novices.

Textbook solution presentations were found to represent the step sequence taken by experts. Novice approaches varied from textbook and expert approaches in sequence. Step sequence was generally not related to novice success. Experts consistently wrote chemical equations for each problem while textbook presentations and novices did not.

Major errors were committed by novices, independent of their previous chemistry grades. Novices recognized problem types and applied learned algorithms rather than analyzing problem systems. When presented with a "disturbed equilibrium system" problem, novices had difficulty visualizing the system and quantitatively adjusting for new concentrations. Students confused amount for concentration but generally knew that concentrations are used in K_c expressions.

Results of this study support previous findings that novices are algorithm or rule learners. Novices depend on problem type recognition and recall of algorithms rather than on analysis of problem systems. No other general heuristics were found.

Findings also confirm that students do not apply the implications of LeChatelier's Principle consistently but employ algorithms instead of analysis in dealing with quantitative shifts in equilibrium problems.

Further work is recommended in equilibrium problem type recognition, problem system visualization, and effects of problem descriptions on novice performance.

AN ANALYSIS OF STUDENTS' CONCEPTIONS OF PRESSURE-RELATED GAS BEHAVIOR

Anasuya Swamy
Morgan State University
Baltimore, MD 21239

Henry Heikkinen
University of Northern Colorado
Greeley, CO 80639

This study was undertaken to describe the knowledge of pressure-related gas behavior that students demonstrated in task performance, and to compare this knowledge with intended learning and the knowledge required to deal successfully with the assigned tasks.

Two principal questions used to examine student knowledge were: (1) What knowledge deficiencies prevent students from completing gas behavior tasks correctly even after instruction? (2) Even among students who perform such tasks correctly, what knowledge deficiencies are still apparent?

Three task systems incorporating aspects of gas behavior were designed. Task procedures and required knowledge for successful task performance for each task were identified, validated, piloted, and evaluated. Following instruction on gas behavior in a first-semester college chemistry course, a random sample of 30 students completed the research tasks. Student knowledge of gas features was extracted and coded from transcribed tape recorded student interviews.

Nearly all (97%) of the sample provided correct predictions and descriptions for the three research tasks. Most students (97%) displayed understanding of the macroscopic relations involving pressure-temperature, and pressure-amount of gas; 67% showed understanding of the pressure-volume relation. Many students had difficulty distinguishing among container area, container volume, and gas volume. Only 3% had a clearly-articulated view of gas pressure, while 75% equated temperature with heat, and more than 50% had missing conceptions involving a molecular view of temperature and kinetic energy. Most low task performers demonstrated knowledge only of empirical gas features, while high task performers showed facility with both empirical and theoretical knowledge. Both groups had missing conceptions or misconceptions regarding a molecular view of gas pressure, kinetic energy, and temperature. In accord with previous research, the findings verified that both theoretical and empirical knowledge of gas behavior are needed for successful task performance.

Recommendations concerning the use of the think-aloud technique, concrete models, and student misconceptions to inform the design of teaching strategies are discussed in light of the findings.

Session A-10

WHAT DOES IT MEAN TO BE AN EXEMPLARY SCIENCE TEACHER?

Kenneth Tobin
Florida State University
Tallahassee, FL 32306

Barry J. Fraser
Western Australian Institute of Technology
Bentley, Western Australia 6102

The somewhat pessimistic findings of classroom research prompted a decision to study "exemplary" science teachers, examine how they taught, and identify successful practices that might be generalizable to other teaching and learning contexts. This study was based on the premise that there are successful science teachers from whom knowledge about teaching and learning can be derived. It was not anticipated that exemplary teachers would be outstanding in every respect, but it was assumed that teachers nominated as exemplary would be good classroom managers and would have some outstanding attributes.

The EPSME study involved a research team of 13 science and mathematics educators from Western Australia, and 26 teachers in schools in the metropolitan area of Perth, Western Australia. The 13 science teachers involved in the study were identified through a nomination process. Key educators in Western Australia, including teachers, State Education personnel and university professors were asked to nominate outstanding teachers of science or mathematics.

Eleven teams were formed to conduct case studies on specific teachers involved in the study. Each team consisted of one or two researchers, although some researchers were involved in more than one team. The teams focused on specific teachers in specific contexts. For example, different teams examined physics, chemistry, biology and general science in the high school. At primary school level, two teams examined science taught in grades six and seven and grades three and five respectively. The number of teachers involved in each of the case studies ranged from one to seven, and two of the science teachers were involved in more than one case study.

An interpretive research methodology was used in the study. The data were primarily qualitative and were obtained by direct observation of teaching by participant observers. The data that were collected consisted of observations of teaching for at least eight lessons, interviews with the teacher and students, and examination of curriculum materials, tests and student work. Written tests and questionnaires were also administered in many of the case studies. Interpretation of data occurred at the individual level, within teams, and at the entire research group level.

The paper presents a synthesis of the six case studies which comprise the science component of the EPSME study. Three sections of the paper discuss strategies used by teachers to facilitate higher cognitive level learning in science, a comparison of exemplary and non-exemplary teachers, and the knowledge and beliefs of exemplary teachers.

The EPSME study provided a substantial knowledge base concerning effective teaching practices in science classes. One challenging outcome of the study is that no matter how good a teacher might be, there will inevitably be some area for improvement. However, the best way to effect change is not clear and it is unlikely that there will be only one best way. The challenge that faces our research group in the wake of EPSME is to identify how teachers can construct knowledge about science content and teaching so that their teaching performance improves.

FACTORS THAT INFLUENCE RURAL SCIENCE TEACHERS AS LEADERS OF DISTRICT IMPROVEMENT PROJECTS

Gail Shroyer
Larry Enochs
Kansas State University
Manhattan, KS 66506

This year-long study was designed to assess the community, organizational, professional and procedural factors that influenced rural science teachers as leaders of science education improvement projects in their districts. Sixteen rural science teachers were selected and trained to plan and implement a science improvement project in their district.

Qualitative and quantitative data were collected pre-, during, and post-implementation to assess the factors that influenced the success of each improvement project. Surveys, interviews, site visitations, and numerous demographic and financial information were collected on each participant, their school and community. These data were analyzed to determine the influence the organizational, community, professional, and procedural variables had on the level and degree of change in each district. The relationships between the independent and dependent variables were analyzed within and between all districts.

The results indicated that the successful utilization of teachers as leaders of science improvement projects was dependent upon a complex relationship between the individual, the school and the community. Strengths in one area were limited by weaknesses in another. Overall, the organization exerted the greatest influence on degree of science improvement that occurred in each district. These results have great impact on the field of education. There currently exists a great interest in the differentiation of teaching roles to encourage career ladders, master teachers, mentor teachers and the overall "professionalization" of teaching. Current plans in this field, however, focus solely on the teacher. Little research exists assessing the factors that support the individual teacher in these new roles. This study demonstrated that science teachers can be effectively utilized to create powerful improvements in science education, especially at the elementary level. Many complex community, organizational, professional and procedural factors must be understood and enhanced, however, before science teachers can be successful in this new improvement role.

AN ANALYSIS OF FACTORS ENCOURAGING CREATIVE TEACHERS TO LEAVE THE CLASSROOM

Barbara S. Spector
University of South Florida
Tampa, FL 33620

This is the case study of six highly successful teachers. A series of hypotheses grounded in the data emerged from this study and provide insight into the psychological climate in schools which contributes to creative, competent, experienced teachers leaving the profession. The perspective that teaching should provide an opportunity for creative expression was central to these teachers' decision making.

Session A-11

AFFECTIVE INFLUENCES ON COMMITMENT TO SCIENCE: A LONGITUDINAL STUDY

J. Steve Oliver
Kansas State University
Manhattan, KS 66506

Ronald D. Simpson
University of Georgia
Athens, GA 30602

The purpose of this study was to determine if attitude toward science, achievement motivation, and science self concept could be used to predict commitment to science. Commitment to science is not defined strictly in terms of a student's desire to major in science, but is also characterized in terms of the student's desire to take more science courses, to continue reading about science, to explore new scientific topics, and to be involved in science-related social issues. For the purposes of this study, commitment was defined in terms of the number of science courses taken, self rating of science ability, and participation in extracurricular science activities. Four affective variables were used to predict commitment to science for the students in the follow-up sample. These attitudes were measured by the Simpson-Troost attitude questionnaire. Included in the group were attitude toward science, achievement motivation in science, science self-concept and interest in reading science.

The original attitude and achievement data for this study were collected during the 1980-81 school year in a large school system in central North Carolina using 5000 students in grades six through ten. The follow-up data were collected during the 1985-86 school year. Two populations, the eighth and tenth grade students, from the original data collections were used in this longitudinal study.

Commitment to science was predicted most successfully by science self-concept. This finding was originally demonstrated in multiple regression models. Students were then grouped into science commitment groups based on the number and type of science courses they took during high school. A predictive discriminant analysis was used to develop a classification rule for these groups. This classification rule was effective in predicting the students who did not continue to participate in science beyond the minimum requirements. The analysis was not sufficiently powerful to distinguish other students.

AFFECTIVE INFLUENCES ON ACHIEVEMENT IN SCIENCE: A LONGITUDINAL STUDY

Ronald D. Simpson
University of Georgia
Athens, GA 30602

J. Steve Oliver
Kansas State University
Manhattan, KS 66506

The purpose of this study was to determine if selected affective variables could be used to predict achievement in science. Achievement in science in most cases refers to the grade made in the science courses attempted by a student. Standardized science scores were obtained during the initial data collection.

The original data collection for this study was conducted during the 1980-81 school year in a large school system in central North Carolina using 5000 students in grades six through ten. This original data collection was designed to assess the change in attitudes and gains in achievement over the course of a school year. Attitude data were collected using the Simpson-Troost attitude instrument, while achievement was assessed from grades made as well as from scores on a test of standardized science achievement specific to the science course in which the student ws enrolled. The follow-up data were collected during the 1985-86 school year. Two populations, the eighth and tenth grade students, from the original data collections were used in this longitudinal study. The follow-up study examined the science courses taken by the students throughout the remainder of their high school career and the achievement made in those courses. Additional data were collected from standardized test scores of general achievement, class rank, courses taken in subjects other than science, and grades made in these courses.

It was shown that achievement in science was as strongly related to concurrent achievement in other subjects as to previous achievement in science. Further, science self-concept was shown to be a significant predictor of achievement in science in most science courses. Attitude toward science and achievement motivation in science were also found to be significant predictors of achievement, but not as widely as science self-concept.

Students were grouped by differential levels of achievement in science versus achievement in other subject areas. For instance, students who scored two or more letter grades lower in science than in mathematics were separated from those students scoring within one letter grade in concurrent mathematics and science courses. A third group was identified consisting of those students who scored two or more letter grades higher in science than in mathematics. A one-way analysis of variance using these groups as the dependent variable in a relationship with each of the four affective variables was conducted. This analysis demonstrated that students who scored two or more letter grades higher in science than in mathematics did report higher levels of attitude toward science and science self-concept.

TRANSACTIONAL ANALYSIS OF THE PERSON-ENVIRONMENTAL INTERACTIONS IN HIGH SCHOOL BIOLOGY AND CHEMISTRY CLASSES OVER THE COURSE OF A SCHOOL YEAR

C. Thomas Gooding
Robert E. Schell
J. Nathan Swift
James H. McCroskery
Patricia R. Swift
State University of New York at Oswego
Oswego, NY 13126

This study compared perceptions of students enrolled in high school biology and chemistry classes with regard to their perceptions of classroom environment and the degree to which they perceive themselves to be congruent with their teacher, their class, and the science they were studying. Data were collected at the beginning and at the end of the school year in order to test the differences between courses of study, time of testing, and their interaction. A multivariate analysis of data collected from 410 students indicated significant differences between the main effects and their interaction. Specifically, students enrolled in chemistry perceived increased levels of student involvement and distance between themselves and their science, while those enrolled in biology perceived a decreased emphasis on finding the "correct answer." These data suggest that educators and researchers may need to be concerned about structural as well as cognitive differences between science courses and that the idea of a homogeneous "science student" who behaves similarly in each course may produce misleading results.

ECO-CULTURAL INFLUENCES UPON STUDENTS' CONCEPT ATTAINMENT IN SCIENCE

Peter Akinsola Okebukola
Lagos State University
Lagos, Nigeria

Olugbemiro J. Jegede
Ahmadu Bello University
Zaria

This study examined the influence of some eco-cultural factors that could exert influence on students' concept attainment in science. The factors of interest were general environment in which the learners spend most of their time, reasoning pattern brought about by the locale, goal structure preference and the nature of the home.

A sample of 128 Yoruba students enrolled in four secondary schools equally drawn from rural and urban settlements were involved in the study. Data collected using the Socio-cultural Environment Scale II and the Science Concept Test showed that learners who live in an automated environment did better (mean = 78.16) than those in a predominately manual environment (mean = 60.16) in the selected science concepts. The results further showed that students whose reasoning patterns were predominantly magical and superstitious did not do as well as those who were empirical in reasoning (t[126] = 14.18, p <.001). It was also shown in this study that most rural dwellers expressed preference for cooperative learning. This group of students did best of all (mean = 69.53) on the Science Concept Test when compared with those students who expressed preference for competitive work (mean = 45.11) and individualistic work (mean = 20.23). Another interesting finding of this study concerns the influence of the home on concept attainment. Students from authoritarian homes achieved less well when compared with their permissive home counterparts. The implications of these results for science teaching, curriculum development and further research are drawn in the paper.

Session A-12

THE USE OF TAKE HOME KITS FOR INCREASING SCIENTIFIC LITERACY IN FAMILIES

Eugene D. Gennaro
Elsie A. Rivard
University of Minnesota
Minneapolis, MN 55455

Recent studies have shown that science instruction is inadequate in the elementary school. Hence, there is a need to provide alternative ways to meet the need for science instruction for interested elementary children. Parents can play a strong role in their children's learning experiences but society has not adequately taken advantage of this potential influence in nurturing a child's interest in science. The study reported here attempts to make use of the family as a motivating influence in children's learning in science. The purpose of the study was to determine the feasibility of the use of science kits for children to be used with their families. The kits were designed to be used with children in the elementary grades and were piloted at two schools in St. Paul, Minnesota. The kits involved doing hands on activities and were checked out through the children's teachers. Each kit is a plastic pencil box and contains a parent card, activity card, student response sheet, and optional activities. A preliminary field testing of several experimental family science kits was conducted by the University of Minnesota during the winter and spring of 1986. End of the year student, parent and teacher evaluations of the kits indicated that students and parents liked doing hands-on science at home. The science content in the kits was not threatening to parents; and teachers were positive toward their use. (No attempts were made to determine whether science knowledge had increased.) Furthermore, parents, students and teachers requested additional kit experiences. It seems possible that kits with out-of-school science activities may be a way to provide an additional means to meet the need of adequate science instruction for children using the family as a motivator.

INTERACTION OF CUES, LEARNER CURIOSITY, VERBAL ABILITY, AND AMOUNT OF INVESTED MENTAL EFFORT WITH ACHIEVEMENT IN A MUSEUM SETTING

Helma M. Fire
Miami-Dade Community College
Miami, FL 33127

John J. Koran, Jr.
Mary Lou Koran
University of Florida
Gainesville, FL 32611

This study investigated the effects that resulted from treatments that differed in the presence or absence of both attention cues and test cues upon learning from a shell museum exhibit. The relationship between students' curiosity prior to, and after, their exposure to a hands-on museum exhibit was also explored. Finally, the interactions of learner characteristics with the above treatments were investigated.

One hundred twenty-nine sixth grade students were randomly assigned to one of four treatments in a modified posttest only design. Subjects were given aptitude tests representing verbal ability and prior science curiosity which were thought to be differentially related to achievement. Exploratory psychomotor curiosity of each subject was timed while each was in the vicinity of the shell exhibit. All subjects were then given posttest measures of invested mental effort, curiosity, and achievement.

Regression analyses revealed no significant main effects for the variance in attention cues or in test cues; merely supplying these cues did not ensure learning. However, this was not discouraging; rather, a significant three-way interaction ($\underline{p} = .04$) of Verbal Ability x Attention Cues x Test Cues was detected with the recall of factual items. Subjects high in verbal ability learned more when the treatment contained test cues, but no attention cues, while low verbal ability subjects could not process the incoming information from the exhibit without the attention cues that provided them with a device for organizing, coding, and remembering the information.

A significant main effect for mental effort was detected ($\underline{p} = .039$). Subjects who invested more mental effort made more and better inferences than those who invested less mental effort. A test cue only treatment seemed to influence students to perceive the task as important to learn; thus they made superior inferences.

A significant interaction ($\underline{p} = .04$) with the Amount of Psychomotor Curiosity x Test Cue was found for posttest science curiosity. A no test cue treatment produced higher posttest science curiosity scores for both high and low curiosity subjects because the subjects could pursue their curious ideas without the threat of being tested on content.

A CROSS CULTURAL ANALYSIS OF STUDENT UNDERSTANDING OF MARINE SCIENCE AND NATURAL RESOURCE CONCEPTS RELATED TO THE GULF OF MAINE

Susan Stillwell
Michael J. Brody
University of Maine
Orono, ME 04469

This study compares relevant conceptual frameworks of Canadian and American students concerning marine science and natural resources in the Gulf of Maine. The results of a previous study of public school students in Maine are compared to a representative sample of public school students in New Brunswick and Newfoundland, Canada. Research methodologies involving student interviews and analysis of student conceptual frameworks are identical between studies. Student knowledge is classified according to correct concepts, missing concepts and common misconceptions. Similarities and differences between grade levels are analyzed and compared between countries and geographic regions. The results of this study will extend our knowledge of student conceptual frameworks especially in relation to cultural and social causes of common conceptions. It is expected that our conclusions will indicate the value of this research methodology and have implications for the development of comprehensive and effective marine science curricula based on international resource issues.

GENERATIVE LEARNING AND ADULT PERCEPTION OF WATER QUALITY: IMPLICATIONS FOR ENVIRONMENTAL EDUCATION

John C. Happs
Western Australian College of Advanced Education
Doubleview, Western Australia 6018

Water is an important resource for all sectors of the community and both the quality and appearance of water bodies are factors of concern for those who manage and use this resource.

A number of government agencies encourage some public participation in the monitoring of water resources. Thus an understanding of individual response to water appearance and quality would seem useful in terms of environmental education programs and encouraging public contribution to water quality control.

This investigation sought to probe the relationships between water quality, from a scientific perspective, and the public's perception of water quality and appearance. Data were collected via individual interviews and questionnaires involving approximately 200 respondents at 3 different water bodies. Questioning elicited their perceptions of water quality both in situ and in samples presented for closer scrutiny.

It has been suggested, in past literature, that non-scientists are likely to judge the quality and appearance of water by visual and olfactory means. Results from this investigation, which used interviews and questionnaires with approximately 200 adult respondents, suggest that widely varying and often unpredictable responses will be given to questions concerning water quality and appearance at different sites.

Wittrock's Generative Learning Model proposes that human learning, with understanding, can be regarded as a generative process involving the construction of:

(1) structures which are organised and able to store and retrieve information;

(2) processes which allow new information to be related to established, stored information.

The whole question of public perception and understanding of water quality appears to be complex and unlikely to be resolved into single variables which determine individual response. Indeed, the influence of "prior knowledge" from media reports, anecdotes and personal bias was evident in this investigation as individuals generated their own understanding of water quality.

Comparisons between the classroom learner and the adult observer of a water-body are useful since both may generate understanding which does not equate with the scientific perspective yet readily meshes in with their prior knowledge.

Impartiality and the consideration of available information should be key elements for individuals striving to construct an understanding of the condition of any water body. This investigation has led to data which strongly suggest that a significant proportion of the public might have difficulty in constructing this understanding in an objective way.

Session B-1

TEACHING FOR HIGHER COGNITIVE LEVEL LEARNING IN HIGH SHCOOL SCIENCE

Kenneth Tobin
Florida State University
Tallahassee, FL 32306

Jane Kahle
University of Northern Colorado
Greeley, CO 80639

Maggie Gremli
10A Hume Heights
Singapore 2159

Barry Fraser
Western Australian Institute of Technology
Bentley, Western Australia 6102

The symposium will focus on issues associated with teaching for higher cognitive level learning in high school science classes. A 10 week study of two classes of above-average high school science students taught by two above-average teachers provided a context for the study. The study took place in an urban high school in Perth, Western Australia. On the basis of the results of the study in which the four presenters participated, four issues which influence student learning emerged. These were the nature of the work in science classes, the roles adopted by teachers and students in a variety of activities, gender related differences in student interaction and engagement, and perceptions of the psychosocial learning environment.

Although we were interested in higher cognitive level learning, there were few opportunities for students to engage at a higher cognitive level during the 10 weeks of the study. The teachers who participated in the study were well qualified to teach science and were highly regarded by their students and their colleagues. However, the research team were deeply troubled by many aspects of their teaching, and we questioned the value of much of what we observed. Each of the presenters in this symposium will address the apparent paradox surrounding the perceived effectiveness of science teaching during the study. We will also highlight the difficulties we faced in engaging in this intensive type of research and the ethical questions we faced in providing teachers with feedback and communicating the results of this research to the broader educational community.

The results of the study have implications for science teacher education programs at the in-service and pre-service levels. In addition, there are implications for further research and the way that classroom research is conducted and communicated. The symposium will also provide insights into the role of teachers in classroom research and will investigate the advantages of science teachers as collaborators in research.

Session B-2

SCIENCE LEARNING IN MUSEUMS AND OTHER INFORMAL SETTINGS

Mary Lou Koran
John J. Koran, Jr.
James Algina
University of Florida
Gainesville, FL 32611

Lynn D. Dierking
Howard Chamber of Commerce
Columbia, MD 21044

John Falk
Smithsonian Institution
Washington, DC 20008

Stephen Bitgood
Jacksonville State University
Jacksonville, FL 32216

Stephen Hage
Minnesota Zoological Gardens
Minneapolis, MN 55455

Eugene Gennaro
University of Minnesota
Minneapolis, MN 55455

Research about science learning in informal settings has received little systematic attention from educators until recently. Because of the largely autonomous nature of this learning, it has resisted careful examination and measurement. Educators have long preferred to investigate phenomena that yield data readily measured and controlled. As a consequence, we know far more about the kinds of learning that are directed by others than about those kinds that are under student control. This picture, however, is shifting, and the forms of autonomous learning and management that comprise learning in museums and other free-choice settings are receiving increased attention.

It is generally recognized that museums and zoos have great potential for promoting informal learning, and progress has been made in recent years toward making them more viable as alternative educational environments. But much more needs to be learned about the variables governing learning in such settings. The purpose of this symposium is to present a set of papers examining research in informal settings and implications for future research from both theoretical and empirical perspectives.

"Families in Free Choice Learning Settings" describes the results of recent research focusing on the role of the family and the nature of interaction among faulty members in influencing attention, curiosity and cognitive level of information exchange. These results will be discussed and possible research questions and approaches to their investigation presented for discussion.

"An Analysis of the Verbal and Postural Communication of Zoo Visitors" also examines the role of the family in promoting learning in the context of a zoo. This study focuses on verbal and non-verbal communication patterns among family members as well as attitudinal data. Results are discussed in terms of the teaching-learning roles assumed by different members of the family, the specific verbal and non-verbal behaviors exhibited and the attitudes formed by family members.

"Toward an Understanding of Perceptions of and Behavior in Museums and Zoos" describes research on the public's perceptions of museums, zoos, science centers and parks, and the extent to which these differing perceptions are likely to affect whether or not people will visit a particular kind of facility. Also discussed are a number of general principles derived from this and other research describing variables influencing the attracting and holding power of exhibits.

"Attention and Curiosity in Museum Learning" examines the feasibility of studying attention in learning using both experimental and naturalistic methods, and also the critical role of attention directing and focusing devices in promoting visitor learning in museum settings. It also describes the interaction of curiosity with attention and the function both play in information processing and science learning in museums.

"A Theoretical Framework for Exploring Research in Museum Education" notes that what appears to be lacking in museum research is an organizing framework for investigating the major variables involved. This paper presents a theoretical framework for exploring important variables in museum research and for identifying promising areas for future investigation. Within this framework four classes of variables will be considered: (1) Visitor characteristics; (2) Processing activities of the visitor; (3) Exhibit characteristics; and (4) Learning outcomes. Museum learning will be discussed as a function of the interaction of all four of these variables. The papers presented in this symposium will be discussed in terms of this framework.

Session B-3

CONCEPTUAL UNDERSTANDINGS AND MISUNDERSTANDINGS OF EIGHTH GRADE STUDENTS OF SELECTED CONCEPTS IN BIOLOGY, CHEMISTRY AND PHYSICS

John W. Renner
Edmund A. Marek
Michael R. Abraham
University of Oklahoma
Norman, OK 73019

Eileen Bross Grzybowski
Norman Senior High School
Norman, OK 73069

The reported research was done during the spring of the 1985-86 academic year. There were two principal purposes for doing the research: (1) To evaluate the understandings of eighth graders of selected concepts in biology, chemistry and physics which they had studied in the seventh and/or eighth grades, and (2) To find whether or not the measured intellectual level of eighth graders is related to their success on understanding concrete and formal concepts.

Questions on four concepts in each of biology and physics and five in chemistry were content validated and classroom tested. The student sample was drawn from seven urban and seven rural schools. Approximately 250 students completed the questions in each discipline but no student completed the questions in more than one discipline. Each participating student also completed two paper-and-pencil measures of intellectual development. All data were collected within a three-week period. Approximately 83 percent of the eighth graders evaluated were concrete operational, nine percent were in transition to formal operations and eight percent had entered the formal thought period. The results show, in general, that formal operational students do better in both concrete and formal concepts than do concrete operational students but there was some success by the concrete students on the formal concepts. That finding led to the conclusion that the relationship between intellectual level and the intellectual demand of a concept is not perfectly linear but that a relationship does exist.

The data were distributed over a scale that measured from no understanding of each concept to sound understanding of each concept. In physics, for example, nearly twice as many eighth graders had no understanding or misunderstanding of the concepts than demonstrated partial understanding and sound understanding. Similar results were found on the biology concepts. The chemistry data have had only a first evaluation, but those early results suggest a similar pattern.

The tentative conclusion has been drawn that many of the concepts found in seventh and eighth grade science textbooks are intellectually beyond the students studying them. Furthermore, the hypothesis was advanced that since some concrete operational students achieved partial understanding of formal concepts, perhaps formal concepts have concrete portions which allow students to reach the partial understanding level. No attempt was made to evaluate how the students had been taught the concepts.

DEVELOPMENT AND EVALUATION OF A PROGRAM FOR LEARNING SCIENCE PROCESS SKILLS IN BIOLOGY

Paul J. Germann
Madawaska High School
Madawaska, ME 04756

This study addressed the need to help high school students develop the critical thinking skills required to solve problems in the biology laboratory. To address this need, the Directed Inquiry Approach to Learning Science Process Skills and Scientific Problem Solving (DIAL(SPS)2) was developed. This lab curriculum integrated several learning strategies into a single approach: directed learning activity, advance organizers, the learning cycle, concept maps, Vee diagrams, Focus: Trial/Evaluate/ Model/Apply/, and writing.

Three research questions were addressed by this study. First, what effect does DIAL(SPS)2 treatment have on the acquisition of science process skills? Second, what effect does DIAL(SPS)2 treatment have on cognitive development? Third, how do academic ability, cognitive development, previous knowledge in content, attitude, language preference, and gender affect the student's ability to learn and to perform science process skills? Three instruments were used to measure science process skills: Dillashaw and Okey's Test of Integrated Process Skills (TIPS), the Processes of Biological Inquiry Test (PBIT), and the Science Process Skills Inventory (SPSI). The PBIT was developed and validated in preparation for this study. SPSI was adapted from work by Tamir and Glassman to evaluate science process skills in the practical mode. Cognitive development was measured by Lawson's Classroom Test of Formal Operations. Student characteristics included academic ability as measured by the SRA achievement test, gender, age, language preference, and attitude toward science. The Attitude toward Science in School Assessment (ATSSA) was developed and validated in preparation for this study to measure how students feel about science as a subject in school.

Four biology classes taught by this investigator were used to test the DIAL(SPS)2 curriculum. Students were not randomly assigned to treatment groups. Scheduling of students involved ability grouping. In order to test the curriculum in the most rigorous way, the experimental group consisted of average ability students and the comparison group consisted of above average students. Both the experimental and comparison groups were pretested in August and posttested in May. In the intervening time, the experimental group received the DIAL(SPS)2 treatment while the comparison group received a more traditional approach.

Analysis of covariance revealed that the DIAL(SPS)2 curriculum had no significant effect on the learning of science process skills or on cognitive development. Aptitude-treatment interaction analyses revealed an interaction of DIAL(SPS)2 treatment and cognitive development. Path analysis showed the contribution of student characteristics to the learning of science process skills. The results are discussed within the context of their implications for research and practice.

THE LEARNING OF PROCESS SKILLS FROM PROGRAMMED INSTRUCTION: EFFECTS OF REVIEW

Barbara M. Strawitz
Louisiana State University
Baton Rouge, LA 70803

The major purpose of the study was to compare the effects of using programmed instruction with two types of review strategies and non-programmed instruction on the science process skill achievement of students enrolled in three intact sections of a science methods class at a large southern university. Students in the three sections did not differ in age or grade point average.

Students in two groups learned process skills from a programmed textbook but during the last two weeks of the semester they completed and turned in different study guides. The study guides required students to write answers to self-test questions about each process skill, but students in one group also answered questions requiring them to identify and explain negative statements about the process skill review questions. Students in the third group learned process skills by participating in hands-on activities taught by the instructor and by peers.

A pretest-posttest nonequivalent control group design was used. Subjects were administered process skill measures at the beginning of the semester and approximately fourteen weeks later. Results of the 3 (treatment) x 2 (time) factorial ANOVA with repeated measures on the time factor revealed a significant treatment X time interaction and a significant main effect for time. Pre-planned comparisons showed that students in the two sections using programmed instruction made significant pre-post gains in process skill proficiency while students not using programmed instruction failed to make significant gains. Results also indicated that while there was no significant difference between groups on the pretest, significant differences in process skill achievement existed on the posttest. Students using programmed instruction significantly outperformed students who did not use programmed instruction. The two review strategies used with the programmed materials made no difference in posttest achievement.

The findings indicate that review strategies did not differentially affect science process skill acquisition from programmed instruction, however programmed instruction was found to be more effective than non-programmed instruction in helping students learn process skills. The results also suggest that students should be required to demonstrate process skill proficiency before they leave science methods classes.

IMPROVING INTEGRATED PROCESS SKILLS IN PRESERVICE ELEMENTARY TEACHERS

Richard Duschl
Terry Contant
University of Houston
Houston, TX 77004

The purpose of the study was to determine whether or not elementary education majors' completion of an independent science investigation would improve their abilities to use and to understand the integrated processes of science. Research on preservice elementary teachers has consistently found such persons display high levels of anxiety toward the learning and the teaching of science. Other research has found that such teachers learn science best when science content is taught separately from science methods. The present study employed a pretest-posttest control group design to investigate the effect a science investigation designed, implemented, and reported by elementary education majors would have on their integrated process science skills.

Subjects for the study were enrolled in one of three sections of an elementary science methods course. Except for the inclusion of the independent science investigation (independent variable) all other aspects of the course across sections were the same. The dependent variable was student performance on the Test of Integrated Process Skill (TIPS) II instrument. A test for homogeneity of regression found no significant differences among students in each of the sections using pretest TIPS II scores. ANOVA results on posttest data did find significant differences at the alpha = .05 level. Scheffe post hoc tests found that students in the treatment group had significantly higher TIPS II scores on the overall test and on each of the subscales of the test.

Results of the study suggest the integrated processes of science are best learned by doing science investigations that require the use of such processes. The established practice of investigating each process through separate activities is less successful. Furthermore, results suggest that the elimination of conceptual knowledge requirements contributes to students' success in learning the integrated processes of science.

Session B-5

GENDER DIFFERENCES IN HIGH SCHOOL SCIENCE IN ISRAEL

Pinchas Tamir
Hebrew University
Jerusalem, Israel

Within the framework of the Second IEA Science Study a representative sample of Israeli 12th grade students (N = 2153) responded to a series of questionnaires and achievement tests in the last term of the academic years 1983 or 1984. The sample consisted of four groups, three of which specialized in one of the sciences each (biology, chemistry and physics) and one comprised of students who did not study any science in their junior and senior years. The purpose of this paper is to report on gender differences in achievement, attitudes, preferences, learning experiences and study habits. The major findings were:

1. The percentage of girls in each of the specified groups were as follows: Biology - 61, Chemistry - 49, Physics - 31, Non-science - 66.
2. More boys perceive themselves as high achievers in science and math.
3. Significantly more boys like to study math and science more than other school subjects.
4. Significantly more boys aspire for science-oriented careers.
5. Boys achieve better than girls in physics and earth science, but their achievement in biology and chemistry is similar to that of girls. The achievement of non-science girls is alarmingly low and, with the exception of biology, much lower than that of boys.
6. Boys and girls do not differ in their attitude toward science and in understanding the nature of science except for the subtest on science and society in which boys excelled.
7. Girls expressed more positive attitudes to school but boys were more interested in science studies.
8. There were no differences in cognitive preferences.
9. Girls report having more inquiry oriented experiences while boys used calculators more than did girls.

The implications of these findings for science education in general and in Israel in particular are discussed.

A STUDY OF SCIENCE AND MATHEMATICS EDUCATION EQUITY

Emmett L. Wright
Nancy Smith
Kansas State University
Manhattan, KS 66506

The purpose of this study was to investigate the factors that may influence the significantly higher ACT test scores in mathematics and science achieved by males when compared to females in a typical Kansas school district. Over a three month period, data were collected and analyzed using standard ethnographic techniques: (1) analysis of student records and experiences; (2) interviews with citizens, parents, school board members and teachers; and (3) student essays.

Significant findings in analyzing records and student essays indicated: (1) students are more likely to have female English teachers and male science and mathematics teachers; (2) the pattern of student participation in extracurricular activities is stereotypical - females differentially participate in fine arts, language clubs, music and school organizations while males, for the most part, participate in sports, computer club, science club and the airplane club; (3) in elementary school books read aloud to students, male protagonists significantly outweigh female protagonists; and (4) in student essays, females perceive more positively being the opposite sex and males perceive being the opposite sex more negatively.

The results of interviewing 27 teachers, parents and school board members were:

1. There is an emphasis in the community for females to assume stereotypic roles.

2. Both the school curriculum and the teachers do not fully offer females the opportunities provided males in the school system, including the selection of course work and extracurricular activities, advisement on college and professional careers, skill development for taking standardized tests, and course materials that treat equally male and female ideas/need/interests.

The findings are nearly classic examples found in the research literature on gender differences in education for the last two decades. For example, the data illustrate the paradox of girls making better grades than boys and lower achievement test scores. The data reveal that the school system is perpetuating problems found in the community: boys are advantaged experientially and the experiences of the students are stereotypical. No one aspect of the data points to this problem. The cumulative impact of being read to about the lives, adventures, and values of males; of having male teachers for science and mathematics, of cheering on the boys rather than being cheered on; and the perception by male students that being female is something negative all contribute to the lowered aspirations of female students observed by teachers and parents.

These findings have serious consequences for the advancement of science and math. A major impact of the lack of science and math literacy of females is reduction of the talent pool of future scientists and mathematicians. The talent pool is seriously limited when female students are not encouraged to participate in science and math courses and see themselves in related careers, and female students (the majority of the student population) are not becoming science and math literate. When communities and their school programs perpetuate stereotypic expectations for females, the reality of a technological future with an increased demand for engineers, medical researchers, environmental educators, and an informed citizenry, etc., may be a harsh reality.

SEX DIFFERENCES RELATED TO GRAPHING SKILLS IN MICROCOMPUTER-BASED LABS

Heather Brasell
University of Florida
Gainesville, FL 32605

As part of an investigation of the effectiveness of a microcomputer based laboratory (MBL) in developing students' graphing skills, this study examines the results for differences between males and females in both performance on graphing tasks and on their attitudes to graphs and graph- based activities. Female students were generally younger, and had lower measures of general ability and development than did males. They reported more difficulty and less enjoyment in working with graphs. After controlling for differences in ability, some sex differences in performance on graphing tasks remained, with females having lower scores for items involving speed or velocity graphs, but not for graphs of miscellaneous graphs of less abstract properties, such as distance.

Graphs constructed by students in a graph construction test revealed that about one-fifth of the students are seriously restricted in their ability to understand graphs by an inadequate graph schema. These students generally thought that graphs were less useful, than did the other students. Females who had poor graph schemas appear to have been constrained by their comparatively low ability, whereas the males were more likely to have been constrained by lack of interest.

For a single class period, students participated in either a series of MBL activities or a pencil-and-paper graph-construction exercise. Students in the MBL treatment gained significantly higher scores on a posttest of distance graphs, but not on a posttest of velocity graphs. This treatment effect was particularly strong for females. Among the students in the MBL treatment, after controlling for differences in ability, females performed better for the distance items, whereas males performed better for velocity items. However, male performance with the distance graphs was constrained by ceiling effects. The MBL experience was effective in improving females' graphing skills, compared with the control activity, but it is not possible to demonstrate who benefitted more--males or females.

A PROFILE DIFFERENTIATING FEMALE COLLEGE SCIENCE MAJORS: A PREDICTOR SET OF VARIABLES

Kathleen G. Sparrow
Akron City Schools
Akron, OH 44313

How can more intellectually capable females be directed into science and engineering careers? Women constitute a large, untapped resource in this country in terms of potential scientific and technological contributions. Concern with increasing the number of females in science professions continues to mount. The purpose of this study was to identify a set of predictor variables and individual variables that would differentiate between college female science and nonscience majors.

The sample consisted of 489 females, 62 science majors and 427 nonscience majors, who earned a Bachelor's degree by 1984 from the High School and Beyond 1980 Senior Cohort. Forty-one variables, representing five areas of interest--demographics, personality, achievement, environment, and interests/values--were examined. Each of these 41 variables was tested for unique variance over and above the other variables. Interactions among selected variables were examined for significance. Multiple linear regression was used to identify predictor variables, unique variance of individual variables, and significant interactions. In addition, a backward elimination was performed to derive a predictor set of variables. A cross-validation technique established relative stability. These analyses found math perceived as being useful in the future, As and Bs in math, number of science courses taken in high school, identifying a college science major as a high school senior and as a college sophomore, and being of the Asian race were significant predictors for female college science majors.

The High School and Beyond data in the 1984 Postsecondary Transcript File allows us to get estimates and potential insights into which variables seem to be most relative to female career decision-making for science or nonscience majors. In addition, the identification of a profile for female science majors will also provide a basis on which to devise intervention strategies to be executed in elementary and middle schools as well as in the high school.

Session B-6

THE RELATIONSHIP OF PROBLEM SOLVING ABILITIES IN GENETICS TO ENCODING AND COMBINING PROPOSITIONS CONCERNING DISJUNCTIVE REASONING

Sandra J. Costello
Rutgers - The Graduate School of Education
New Brunswick, NJ 08903

Since it can be demonstrated that disjunctive reasoning is related to the fundamental concepts of genetics (gamete formation and gamete combination), it was the purpose of this study to investigate competency and application of disjunctive reasoning through written tasks and verbal protocols. The written tasks were designed to measure encoding and combining propositions, as well as problem solving ability in genetics. The verbal protocols obtained during solving and interview sessions provided information about the nature and frequency of use of the disjunction connective.

Results from the encoding and combination tasks as they relate to solving the genetics problems revealed significant relations. The genotypes problem being the most difficult was significant with the combination task for the inclusive disjunction. It was inferred that subjects with clearly defined inclusive and exclusive interpretations were more successful at solving this problem which focused on gamete formation - an exclusive process.

The problem solving behaviors as indicated in the literature on misconceptions and expert-novice studies were also supported. A model for competency in mathematical problem solving was used to organize the problem solving behaviors in this study. It was concluded that these behaviors were manifestations of the subject's ability to establish and manipulate logical relations using the disjunction and the ability to encode and combine specific subject matter knowledge using these relations.

A DESCRIPTION OF THE PERFORMANCE OF EXPERTS SOLVING REALISTIC GENETICS PROBLEMS

Angelo Collins
Kansas State University
Manhattan, KS 66506

James H. Stewart
University of Wisconsin-Madison
Madison, WI 53706

The purpose of this study was to describe the strategic knowledge used by experts to solve realistic, computer-generated transmission genetics problems. Seven people with doctoral degrees and experience in teaching and research in different areas of genetics solved problems while thinking aloud. The computer program GENETICS CONSTRUCTION KIT (GCK) was used to generate problems. In GCK the solver determines the inheritance pattern by continually producing data. The classes of problems attempted by the experts were two trait problems with simple dominance, codominance, or multiple alleles as inheritance patterns and sex linkage or autosomal linkage as modifiers.

The description consists of three categories of strategic knowledge: data redescription, solution synthesis and solution assessment. Data redescription strategies permit the solver to limit the problem space by identifying the essentials of the problem. In genetics, data redescription includes identifying the number, name, and distribution of variations for a trait and occurs whenever an inheritance pattern hypothesis is formulated. Solution synthesis strategies assist the solver in planning and executing ways to search the problem space. The solution strategy used by genetics experts is hypothesis testing. Two types of hypotheses are tested - general hypotheses about inheritance patterns and specific hypotheses about the distribution of variations to offspring in a cross. In each class of problems there is one cross, requiring the identification and use of an heterozygote, that is used to determine the inheritance pattern. Solution assessment strategies allow the solver to determine that the answer is as complete and accurate as possible. Experts in genetics assess the solution to realistic problems by confirmation, that is, by collecting additional data after the inheritance pattern hypothesis has been determined.

The description of expert performance is being used in the design of the computer tutor program, MENDEL. It is also providing insights into the design of clear and explicit instruction in problem solving in transmission genetics. The description also indicates that experts have compiled much content knowledge that is available to interact with strategic knowledge.

STUDYING LEARNERS' PROBLEM SOLVING STRATEGIES AND RATIONALES DURING A COMPUTER SIMULATION

Patricia Simmons
The University of Iowa
Iowa City, IA 52242

Previous research studies have reported characteristics of successful and less successful problem solvers using written genetics problems. CATLAB, a genetics computer simulation, served as the interactive medium for studies focusing on problem solving strategies and rationales and decisions of "expert" and "novice" subjects investigating inheritance patterns. A microcomputer-VCR interface recorded subjects' interactions with the software during a "think aloud" protocol. The videotapes were transcribed and analyzed for behavior patterns, strategies, and rationales subjects utilized during exploration and hypothesis testing phases of the learning cycle. Analyses of the videotapes revealed similar and contrasting behavior patterns and rationales between individuals of each group and between the two groups. One contrasting behavior between novices and experts was the treatment of sufficient sample sizes, while the majority of novices drew their conclusions without verbalizing the limitations. These behaviors will be discussed and interpreted as part of a multi-level problem solving model. An array of research studies is needed to enhance our understanding of problem solving, particularly on how learners progress from "novice" to "expert" problem solver. The findings from studies described here would enable science educators and science teachers to facilitate opportunities for learners to develop and enhance problem solving skills.

Session B-7

PROBLEMS AND ADVANTAGES OF A LARGE-SCALE EXTERNAL RESEARCH/EVALUATION AGENDA ON A NATIONALLY IMPLEMENTED PROJECT: THE NSF/NSTA HIGH SCHOOL CHAUTAUQUA EVALUATION

Russell H. Yeany
Elisabeth Charron
Hsiao-lin Tuan
University of Georgia
Athens, GA 30602

John Fowler
National Science Teachers Association
Washington, DC 20069

Carolyn Hampton
East Carolina University
Greenville, NC 27834

Kenneth R. Mechling
Clarion University
Clarion, PA 16214

Large-scale, multiple-site programs present exciting opportunities for creating a regional or national impact on science education. Although the programs offered at each site may be linked by a guiding philosophy or cluster of objectives, the sponsoring agency may encourage sites to develop individualistic offerings. If the sites are widely separated geographically, program diversity may become even more pronounced. While heterogeneous national or regional science education programs may be desirable, they present unique problems for both the external evaluator and the evaluated when the time for assessment arrives. This symposium begins with an overview of such a program from the viewpoint of its sponsoring agency; proceeds to descriptions of the problems identified and the evaluation design developed by the external evaluators; and ends with two reactions to the evaluation design by site directors. Although each presentation refers to the NSTA Chautauqua Short-Course Program for secondary teachers, a particular nationally-supported program, links are explicitly established between this program and other wide-net, multiple-location programs. Evaluation problems examined range from the need to provide appropriate feedback at both the national and local level, to the difficulty of achieving content validity for multiple instruments at each site, to the need to ascertain site staff members' initial attitudes toward evaluation, to practical matters such as maintaining adequate communication with distant sites.

In addition to discussing the problems of the large-scale external research/evaluation agenda, the advantages of such an effort are brought out in relation to benefits derived at the state sites and to the richness of information from such an effort.

Session B-8

A SYNTHESIS OF RESEARCH ON THE EFFECTS OF TEACHING SCIENCE WITH MICROCOMPUTERS

Kevin C. Wise
Southern Illinois University
Carbondale, IL 62901

The primary purpose of this study was to obtain, examine, and synthesize the findings of reports and investigations in which the effectiveness of microcomputer-based science instruction was examined through comparison to traditional instructional approaches. A further purpose was to compare the various types of microcomputer-based instructional approaches identified to determine if one type of approach was more effective than the others. Based on this synthesis of the literature, recommendations of practical value can be made to teachers, and questions for future study can be made to researchers.

Research reports dated January 1980 and later were identified by using the Resources in Education (RIE), Current Index to Journals in Education (CIJE), and other appropriate sources. Once identified, individual documents were further examined to determine if they were actual studies of microcomputer-based science instructional approaches and if they met specified minimum criteria such as inclusion of a control or contrast group and use of objective assessment measures. Meta-analysis was used as the primary technique for integrating the findings of all studies determined to be appropriate.

To date, seventeen reports have been selected for inclusion. From these studies nineteen effect sizes representing both cognitive and affective measures have been computed. The overall mean effect size is +.57. Thus, based on seventeen reports, the microcomputer-based approaches were more effective than the traditional instructional approaches to which they were compared. Further, simulations were the most effective type of computer-based instruction.

Although the number of studies synthesized is not great, the trend favors microcomputer-based instruction in certain instances with approaches involving simulation type programs being of particular value.

TEACHER BEHAVIOR IN WHOLE CLASS, COMPUTER-MEDIATED INSTRUCTION

Theodore Kellogg
University of Rhode Island
Kingston, RI 02881

Carol Leonard
Lemon Bay High School
Englewood, FL 33533

This study examined teacher behavior in a classroom setting in which a single computer was an integral part of the presentation of a lesson. One computer using a video projector for output display was present in the room. Teachers using these materials were expected to shift their role from lecturer and conclusion-drawer to initiator and facilitator.

Students were presented information by the computer, and key questions were asked by the computer. The teacher moderated the discussion, calling on students, asking additional questions, and arbitrating disputes. Project materials were used by eight teachers in one or two classes for three or four days. The biology content of the lesson was drawn from genetics. The inquiry skill focused on was hypothesis testing.

Data included videotapes (analyzed for teacher questioning behavior), a post teaching questionnaire from the teachers, a group interview/debriefing session with the project teachers, a student questionnaire and project staff observations of the classes.

Teachers averaged asking 43 to 93 questions per class. Teachers differed in the number of questions asked in each lesson. The project teachers varied in the percentage of high level inquiry questions each asked. High inquiry questions varied from 35 to 50% of the questions asked by each teacher, with an average for the project of 43%. Teacher reports, project staff observations, and student questionnaire data were analyzed.

The project showed that the use of a single computer in an instructional role in a whole class setting is a viable instructional model. It appears that the teacher behavior can be modified in the desired direction by the use of the computer.

ENLIST - *MICROS: TRAINING SCIENCE TEACHERS* TO UTILIZE MICROCOMPUTERS

William E. Baird
Auburn University
Auburn, AL 36849-3501

Jim Ellis
Paul J. Kuerbis
The Colorado College
Colorado Springs, CO 80903

A National Science Foundation grant to BSCS at The Colorado College supported the design and production of training Materials to ENcourage LIteracy of Science Teachers in the use of MICROcomputerS. ENLIST-Micros is based on results of a national needs assessment, which identified 22 competencies needed by K-12 science teachers to better utilize microcomputers for instruction. The 15-hour training program was developed by a writing team in the summer of 1985 and pilot tested in preservice and inservice environments during the 1985-86 academic year at selected sites around the country.

The training materials consist of video tape, interactive computer disks for the Apple II series microcomputer, a training manual for participants, and group leader guide. The materials address major areas of educational computing -- Awareness, Applications, Implementation, Evaluation, and Resources. Each chapter contains suggested activities, which include viewing of video tape segments of science teachers using computers effectively as well as use of commercial science software and training courseware developed for this program. Role playing and small group interaction help teachers overcome computer anxiety and plan for effective implementation of microcomputers in the school.

Results from one pilot test center indicate that both elementary and secondary teachers benefit from the training program and attain more positive attitudes toward computer use. Teachers who participated say that the program meets its stated objectives, and helps them obtain needed skills.

THE USE OF CONCRETE, MANIPULATIVE MATERIALS AND COMPUTER SIMULATIONS FOR LEARNING ELEMENTARY SCHOOL SCIENCE PROCESS SKILLS IN TRINIDAD AND TOBAGO

Arthur L. White
The Ohio State University
Columbus, OH 43210

Donna F. Berlin
The Ohio State University at Newark
Newark, OH 43055

Pamela F. Abder
The University of the West Indies
St. Augustine, Trinidad, West Indies

The theoretical framework for this research is based upon modes of representation. It is suggested that learning progresses along a mode of representation continuum from concrete to semiconcrete to abstract. This continuum has been translated into instructional practice as manipulation of physical objects, pictorial or graphic representation, and finally symbolic form. This research was designed to determine the optimum combination of science process learning activities involving concrete, manipulative materials and microcomputer simulations for West Indian elementary school children in Trinidad and Tobago. The children had little or no experience with manipulative materials or computers prior to the research. The children were in second grade (ages 6 to 7) and fourth grade (ages 8 to 9). There were 28 boys and 38 girls in the sample. The three treatment conditions involved computer only, manipulatives and computer, and manipulatives only learning activities. There were no differential effects between the use of manipulative materials and the computer. There was a greater difference between the scores of the 2nd and 4th grade girls than between the scores of the 2nd and 4th grade boys. There was also a significant grade level effect with 4th grade scores consistently higher than 2nd grade scores on both scales (Design Recognition and Patterns).

Session B-9

ANALYSES OF SELECTED COGNITIVE ABILITIES AND OTHER FACTORS ASSOCIATED WITH ACHIEVEMENT IN A BIOLOGY PREPARATORY COURSE AND BEYOND AT AN URBAN COMMUNITY COLLEGE

Carol Biermann
Gary Sarinsky
Kingsborough Community College, City University of New York
Brooklyn, NY 11235

A study was undertaken to determine the effectiveness of a biology preparatory course in developing the proper skills necessary for students to achieve in follow-up courses in biology. In addition the factors associated with success in the preparatory course and follow-up courses were ascertained.

It was determined that 57% of the students enrolled in the preparatory course passed the course while 43% either failed or withdrew. Only 142 (44%) registered for follow-up courses in biology. Of this group 37% passed. This represented 16% of the original preparatory group.

One-way analyses of variance pointed to mathematics, age, and reading score as being significantly related to pass/fail in preparatory biology. A stepwise discriminant analysis exhibited mathematics as the principal discriminating variable for pass and fail groups in preparatory biology. The percent correctly classified was 67%. A stepwise multiple regression analysis also determined that mathematics, reading and type of high school degree explained some 33% of the variance.

In addition, a stepwise regression of the follow-up courses revealed that their initial follow-up grade and their biology preparatory grade explained 77% of the variance. The preparatory grade is a good predictor of success in follow-up courses.

STUDIES ON COGNITIVE DEVELOPMENT IN A NON-MAJORS INVESTIGATIVE GENERAL BIOLOGY LABORATORY.

Alan R. P. Journet
Cindy C. Young
C. Michael Stanley
John S. Scheibe
Southeast Missouri State University
Cape Girardeau, MO 63701

Recent studies on cognitive development of students in the general biology course at Southeast Missouri State University have addressed three hypotheses: that cognitive development of college students is promoted by an investigative general biology laboratory course, that gender is a predictor of cognitive development, and that cognitive development and gender influence performance in the course. A pencil and paper test of cognitive level was used as the dependent variable in step-wise multiple regression and canonical correlation analyses with a range of independent variables measuring student and course characteristics. These analyses revealed that cognitive development occurred with a laboratory manual that emphasizes investigation and employs pedagogical techniques that take into consideration student cognitive limitations, that gender is not a predictor of cognitive development, and that neither gender nor cognitive development are predictors of performance in the course. Positive predictors of cognitive level were science and mathematics interest and number of mathematics courses while enrollment in developmental courses was a negative predictor. Significantly absent as predictors were science courses, number of credit hours accumulated, and age.

THE EFFECTS OF A SCIENCE LITERACY COURSE ON SUBSEQUENT LEARNING IN BIOLOGY

Dale R. Baker
University of Utah
Salt Lake City, UT 84112

Michael Piburn
Westminster College of Salt Lake City
Salt Lake City, UT 84105

Two hundred and forty-nine freshman subjects were enrolled in an intervention course to teach scientific literacy skills. Arons' definition of literacy and Piagetian theory guided the selection of materials, teaching strategies, concepts, processes, and course placement. The course was hands on, inquiry oriented, and did not use a textbook. Students were enrolled in the course for one school year. The following year the students were placed in one of three ability levels in biology: basic, intermediate, and advanced. This placement was determined by teacher judgment and student choice. The students were pre and post tested for biology achievement using the Scott

Foresman Comprehensive Assessment Program, High School Subject Test (R=95) at the beginning and end of the school year. Then three comparison groups were randomly chosen from previous classes who had also taken the biology achievement test, but had not had the intervention. These two groups were compared for achievement. Students enrolled in the literacy course did better in biology than those who did not have the course. This was especially true for the part of the test called scientific reasoning. Students in the intermediate and advanced classes benefited most from the intervention. There were no sex differences. Teachers felt that students were better prepared to learn content and less time had to be spent teaching students how to do such things as graphing or proportions. One can conclude that a course designed to teach scientific reasoning provides students with the skills to be successful in the content area of biology.

CORRELATES WITH STUDENT PERFORMANCE IN GENERAL BIOLOGY LECTURE AND LABORATORY COURSES

Patricia (Smoot) McDaniel
Alan R. P. Journet
Southeast Missouri State University
Cape Girardeau, MO 63701

The Department of Biology at Southeast Missouri State University offers two general education courses: A lecture and a laboratory. The lecture course is a "principles and processes" course dealing with the fundamental biological concepts of science, genetics, evolution and ecology. The laboratory course is investigative, with a primary goal of teaching the process of scientific investigation and formal operational thought. Over 550 students enrolled in general biology lecture and general biology laboratory participated in a study designed to determine which from a number of variables assessing student characteristics were predictors of, or correlated with, student performance in these courses, and which predicted course completion. A 27 item questionnaire covering general areas of science experience, attitudes, academic preparation and involvement in non-academic activities provided the independent variables. Student performance and course completion were used as the dependent variables. Statistical analyses revealed developmental writing as a negative predictor of student performance in both courses. Number of college biology and science courses, and science and biology interest were positive predictors of performance in the laboratory course. Science interest, comfort with mathematics, and hours involved in non-academic activities were positive predictors of performance in the lecture course. Developmental writing and developmental mathematics were negative predictors of lecture course completion. Interest in biology was indicted as a positive predictor of laboratory course completion. There is a noticeable absence of high school science and high school biology as predictors of performance and course completion in either of the courses.

Session B-10

THE EFFECTS OF TRAINING AND USE OF SPECIALLY DESIGNED CURRICULUM MATERIALS ON CONCEPTUAL CHANGE TEACHING AND LEARNING

Edward L. Smith
Charles W. Anderson
Michigan State University
East Lansing, MI 48824

Students generally enter science courses with beliefs about how the world works that are reasonable but incompatible with accepted scientific theories. Learning with understanding can occur only through a complex process of conceptual change. Instead, most students memorize enough to pass tests while continuing to hold misconceptions.

However, a number of studies have demonstrated that this need not be the case. We have concluded from previous research that often teachers are not successful because they generally lack the knowledge they need to produce conceptual change in their students. We have hypothesized that successful teaching for conceptual change depends on knowledge of two types: a general orientation toward conceptual change and specific knowledge, including:

1. Knowledge of science content and curricular goals.
2. Knowledge of students and their specific misconceptions.
3. Knowledge of conceptual change teaching strategies.

Our previous research has involved developing knowledge of each type and making it available to teachers, primarily through instructional materials designed for that purpose. The goals of the present study were:

1. To investigate the nature of the knowledge bases used by science teachers and the relationship of those knowledge bases to effective teaching practice.
2. To compare the effectiveness of different methods of improving teachers' knowledge.

In particular, we wanted to investigate the potential contributions that training alone and in combination with the use of our materials would make to teachers' knowledge, their teaching behavior, and student conceptual change learning.

The study involved 13 seventh grade life science teachers who each taught two units (on photosynthesis and respiration) for which they were provided conceptual change-oriented training or materials or both. All teachers taught a third unit (on matter cycling) without being provided any materials or additional training. Teachers were interviewed concerning their teaching of each unit. Observational data on conceptual change teaching strategy use were collected as well as pre, post, and delayed posttest data reflecting the students' conceptions of each topic.

Teachers used conceptual change strategies more frequently if they were using our materials than if they were not. Likewise, student learning was superior when teachers were using our materials. The training had no significant effect on either. Neither training nor use of our materials on the first two units resulted in high levels of conceptual change strategy use or student learning on the third unit.

These results provide further evidence that the recommended teaching strategies do promote conceptual change learning. However, they also indicate that these strategies are difficult to implement without the use of curriculum materials which support their use. Modest amounts of training and experience with using conceptual change oriented materials are insufficient to enable even conceptual change-oriented teachers to acquire the necessary specific knowledge and successfully adapt available materials under normal circumstances. Conceptual change-oriented research and development of curriculum materials is a long range approach with obvious promise.

An additional implication for research is the need to explore more extensive professional development activities focusing on the specific knowledge for particular topics and the selection and adaptation of curriculum materials.

REDUCING READING ASSIGNMENTS TO FOCUS ATTENTION ON SELECTED SCIENCE CONCEPTS

Ann Benbow
Thomas O'Brien
Chris Clermont
Judith Philippides
Russell Wright
Elizabeth Wharton
University of Maryland
College Park, MD 20742

There seems to be little doubt among many science educators that a majority of science teachers depend heavily upon science textbooks, yet little research has concentrated on the effects of using science texts taught under varying conditions.

Anderson & Armbruster, in their review of research on "Studying" text, conclude that teachers need to help students focus their attention on the information that is of greatest importance and to inform students regarding the nature of the criterial tasks with the goal of facilitating encoding (e.g., recall, comprehension). Furthermore, Andre theorizes that students selectively attend and encode information with the goal of satisfying the perceived demands of the teacher. Thus, teachers must help students in their perception of tasks by directing their attention to the concepts of greatest importance. In this regard, Anderson & Armbruster in the review of research on "Content Area Textbooks" recommend that teachers focus students' attention away from text information that is of lesser importance through the use of adjunct instructional aids or some other form of direct instruction. One form of direct instruction easily available to teachers is the assignment of pages in students' textbooks.

Students (n=128) enrolled in a ninth grade biology course using the text, Biological Science: An Inquiry Into Life (4th Edition, BSCS Yellow Version) were used as the sample in this experiment. They were randomly assigned to the: (1) reduced-text group, (2) extended-text group, or (3) a placebo-control group.

Students completed a 25 multiple-choice question test measuring comprehension as defined by Holliday, Whittaker and Loose. Each question presented (in the stem) a new example of one of the five targeted concepts and five alternative choices - the five single-word labels used to describe each concept presented to the reduced-text group.

Analysis of variance of the comprehension tests scores resulted in powerful differences among the three groups, F (2, 126) = 34.96, MSe = 762.28, $p < .05$. A subsequent multiple range test of group means (Newman-Keuls Procedure) substantiated the significant differences among the groups, as predicted. The following statistics illustrate the unusual power of the experimental results: (1) placebo-control group mean, 12.0, standard deviation, 3.5; (2) extended-text group mean, 15.8, standard deviation, 5.6; and (3) reduced-text group mean, 20.4, standard deviation, 4.8. Thus, the extended-text group mean scores were about 30% higher than the placebo-control, and the reduced-text groups mean scores were about 30% higher than the extended-text group mean scores.

The comparable performances of the placebo-control and extended-text groups substantiated the hypothesis that the reading material used in this study effectively enhanced comprehension of the targeted concepts - a point assumed by many researchers but often not empirically established in their experimental studies. This study supported the model of selective attention generally described by Anderson & Armbruster and Andre and extended its potential explanatory power to a form of direct instruction available to every science teacher.

THE EFFECTS OF PRIOR KNOWLEDGE ON SCIENCE TEXT COMPREHENSION

Fred N. Finley
University of Minnesota
Minneapolis, MN 55455

In spite of the extensive use of text in high school science classrooms and the accompanying problems for students, relatively little is known about how students' prior knowledge of a topic changes as a result of their reading and studying science text. The purpose of this study was to describe such changes when students read text explaining the transfer of thermal energy using kinetic molecular theory. The population was eleventh grade chemistry students with a wide range of academic abilities. Twenty four students were randomly selected from typical eleventh grade chemistry courses and assigned to either a control group or experimental group. The students assigned to the experimental group were asked to read and study a text passage related to thermal energy transfer as if they were going to be tested on the material. The same instructions were given to the students in the control group who read a passage describing properties of water. All students were asked to describe and explain their observations of thermal energy transfer during a clinical interview one week before and one week after they read and studied the text passage. The transcripts of the interviews were analyzed by decomposing each student statement into sets of propositions. Comparisons of the proposition sets revealed that: (1) students usually provided an explanation based on a "heat as a substance" theory or a kinetic molecular theory, (2) the pretest effects of the interview were minimal, (3) those students whose prior knowledge was consistent with the text content extended and refined their knowledge and (4) that when prior knowledge was based on a different theory than was presented in the text, students assimilated portions of the text in a way that was consistent with their prior knowledge without changing it in a fundamental way. These results in conjunction with theories of conceptual change suggest that text materials and instructional strategies that: (1) build on students' correct prior knowledge, (2) challenge misconceptions, (3) explain the inadequacies of the misconceptions, and then (4) present a plausible alternative may be more effective than those that do not attend to students' prior knowledge.

Session B-11

RESEARCH BASIS FOR A MODEL OF PROBLEM SOLVING IN SCIENCE

Ron Good
Louisiana State University
Baton Rouge, LA 70803

Using the expert-novice approach, problem-solving research in physics, biology, and chemistry has resulted in many similar conclusions about successful problem solvers. They perceive problems as tasks requiring analysis and reason, break a problem into sub-problems, develop knowledge as a part of the solution process, group problems according to broad science concepts, make frequent checks, etc. Unsuccessful solvers seem unable to do these things and more, and they often reflect persistent misconceptions/naive theories about how nature operates.

The research basis for a model of problem solving in science is drawn from expert-novice studies related to information-processing theory and from cognitive-development research related to the Piagetian/Genevan model. Problem solving is viewed as a test of understanding natural phenomena such as that studied in introductory biology, chemistry, and physics.

Successful problem solving is compared to unsuccessful problem solving in terms of specific science content schemas and general reasoning indicators. The common general characteristics of successful problem solvers in classical genetics, chemical equilibrium, mechanics, and other content areas are interpreted within the contexts of knowledge representation and heuristics.

Teaching students to become better problem solvers in science requires the teacher to have accurate diagnostic tools and a repetoire of materials and techniques. These assume accurate conceptions of science by teachers and practical knowledge about students. Teachers must know how students reason in a general sense (e.g. concrete, formal) and how students are likely to process new information, given that students hold certain inadequate conceptions of how nature operates.

Implications for teaching require that considerable time be spent on collective as well as individual diagnosis and that challenges to misconceptions/naive theories be made by fellow students as well as the teacher. Modifications to the Karplus/Renner learning cycle are proposed, based on the model outlined in this paper. The role of questioning is a prominent part of the research base and resulting model of the teaching and learning of science problem solving.

RELATING FORMAL AND PHYSICAL KNOWLEDGE

Warren Wollman
University of Rochester
Rochester, NY 14627

Since previous studies from a variety of perspectives have shown that students do not as a rule deliberately integrate knowledge into higher order structures, a study was undertaken to see how students made sense of their first encounters with formulae in a science course. Thirty junior high school eighth and ninth graders of above average ability were interviewed to determine whether and how they related formal and physical knowledge of density, a topic they had recently studied. Students were also given various prompts to relate prior knowledge of speed and unit cost to their knowledge of density and, if appropriate, to generalize their knowledge to an unfamiliar concept (pressure) presented to them during the interview. Teachers were also interviewed regarding their students' ability to integrate knowledge on their own and how to teach them to do this. As a rule, the students made no connection between the formal and physical knowledge and could not say why the formula D=M/V was reasonable in the light of their physical knowledge of the concept and the way the term "density" was used to describe or explain that knowledge. Prompts to relate density and its formula to more familiar concepts and their formulae (speed, unit cost) were unproductive. However, prompts to relate transformations or actions related to changes in density to transformations related to the formal definition of the term were fairly successful. Half the students could use this kind of prompt and most of those who did could also generalize to a new concept. It is not clear to what extent the remaining students understood an explanation of how to use the prompt regarding transformations; most of them could not transfer to a new concept. Teachers did not make any explicit attempts to justify the form of the formal definition even though their assessment of their students was that they would be extremely unlikely to make any connections on their own. The teachers doubted whether it would be worth the effort to try to teach students a more profound understanding of the origin or validation of formal representations of physical knowledge. This research suggests that such efforts might well meet with success.

THE EFFECTS OF TEACHING LOGICAL REASONING UPON STUDENTS' FORMAL REASONING AND SCIENCE ACHIEVEMENT

Linda W. Crow
Sue G. Haws
Houston Community College System
Houston, TX 77007

One of the goals of science education has long been to develop scientifically literate and concerned individuals with a high competence for rational thought and action. Science, by its very nature a logical discipline, requires for the scientists certain rational skills to solve problems. One of the components of rational thinking is the ability to reason formally. This study investigated the development and effectiveness of materials designed to enhance formal thinking skills and science achievement. These materials were developed by the authors and integrated into a community college geology course. It was found that the students not only achieved higher on a geological achievement test, but also increased their formal reasoning skills.

AN ANALYSIS OF SELECTED TOPICS IN HIGH SCHOOL CHEMISTRY FROM A COGNITIVE DEVELOPMENT PERSPECTIVE

Stephen R. Rumsey
Acton-Boxborough Regional High School
Acton, MA 01720

This study was designed to identify the levels of difficulty encountered by high school chemistry students on topics related to proportional thinking, and then to discover to what extent student performance on these selected chemistry topics was dependent on performance on selected cognitive development tasks.

Two hundred and fifteen high school chemistry students responded to a 40-item chemistry retention test following a year of chemistry classroom instruction. A series of Piagetian-like classification measures, including the Test of Logical Thinking and a battery of three Piagetian-like puzzles was also administered to each subject. Hierarchies of difficulty were constructed based on test items clustered by chemistry topic and expected cognitive skill. These hierarchies were developed using the Ordering-Theoretic Method with the McNemar Test as a measure of statistical significance. Empirically-derived hierarchies were compared to Piagetian classification and to theoretical hierarchies developed by separate panels with expertise in Piagetian theory and chemistry content.

Results of hierarchical analysis indicated that item difficulty was more dependent on cognitive skill requirements than on chemistry topic. Cognitive skills, such as inverse proportional reasoning and direct proportional reasoning with numbers other than small whole numbers, were dependent on first-order direct proportional reasoning as measured by subtests of the classification measures, but not on an overall formal operational classification.

Results confirmed that most high school chemistry students operate at the concrete operational level. Test items that contained small whole number ratios did not require formal operational skills. Some formal operational items were answered correctly by using alternative strategies such as the use of algorithms or the factor-label method.

Implications for teachers are that chemistry instruction can be improved by providing more concrete referents and properly designed demonstrations and laboratory work. Curriculum changes, including a spiral approach in which formal operational topics are visited often during the year in a pattern of ever-increasing complexity, are desireable. A proposed curriculum based on the findings is presented.

Session B-12

INTERACTION OF ABILITY WITH WAIT TIME AND SUPPORTIVE INTERVENTION IN BIOLOGY AND CHEMISTRY ACHIEVEMENT

J. Nathan Swift
James H. McCroskery
C. Thomas Gooding
Robert E. Schell
Patricia R. Swift
State University of New York at Oswego
Oswego, NY 13126

The objective of this project was to enhance classroom questioning and discussion skills in order to increase scientific literacy and problem solving performance, leading to improved achievement. The major focus was to improve instructional procedures and practices through wait time and supportive intervention.

In this study of the effects of wait time and supportive intervention of student achievement in biology and chemistry, 44 teachers in 15 high schools reported data on student achievement test scores and student self-reported ability levels. There were 22 biology and 22 chemistry classes included with 505 biology and 442 chemistry students in the sample. Regents Examination scores in biology and chemistry were evaluated by two separate univariate analyses of variance using the variables of wait time, supportive intervention, and ability level.

Scores were significantly higher in chemistry classes and in high ability biology classes when wait time feedback was provided. Supportive intervention did not produce a significant effect in chemistry. In biology, scores were lower for the supportive intervention condition. The lower scores may result from the focus, in the biology classes studied, on memorization of facts and definitions whereas the chemistry classes were found to place greater emphasis on problem solving and analysis.

THE EFFECT OF QUESTIONING TECHNIQUES, WAIT TIME, AND VERBAL QUIZZES ON THE ACHIEVEMENT OF STUDENTS IN LAB BASED GENERAL BIOLOGY

Michael J. Demchik
Jefferson High School
Shenandoah Junction, WV 25443

The purpose of this study was to investigate the effects of cognitive questioning, wait-time and verbal quizzes on student achievement during the second semester of general high school biology, 1985-86. The format was devised as part of a 50% laboratory based program because of the students' poor attitude toward and mediocre achievement in general biology during the first semester.

During the second semester, 57 students in three biology classes received varied instructional strategies. The instructor was the same for all three classes. In one lab class, the instructor responded only to student questions, and in two classes used a three second wait-time and asked lower and higher level questions. Only one class received short verbal quizzes at the end of each completed lab. All labs preceded discussion and limited lecture on each new topic.

Analysis of variance (ANOVA) of the data indicated that student achievement was significantly greater for the class that had a three second wait-time, and received verbal quizzes at the end of each lab. Multiple analysis of variance (MANOVA) indicated that there was no significant difference in achievement for boys and girls when class and sex were used as the independent variables and semester percentages as the dependent variable. Attitudes toward general biology showed a 50% change from the first semester to the second.

MIND GAMES: A STUDY OF HYPOTHETICAL QUESTIONING IN A SCIENCE CLASSROOM

Ann E. Haley-Oliphant
University of Cincinnati
Maineville, OH 45039

The purpose of this study was to examine the thinking underlying hypothetical questions posed by a science teacher. This study examined the origins and functions, the characteristics and the preparation, interaction and evaluation involved in this line of questioning. The study was built on recent research on teacher thinking, the complexity of the classroom and on the use of questions by teachers. The study was conducted in a suburban junior high with a teacher having five years teaching experience. Naturalistic methods were used to acquire the data, including field notes, audiotape and videotape recordings, and structured interviews with the teacher and the students. Data were analyzed using the technique of constitutive ethnography.

Preliminary findings indicate that this line of questioning has two functions. First, these hypothetical situations serve to provide the opportunity for students to engage in critical and creative thinking and to give the teacher and the students a chance to make science "wonder"-ful. A series of characteristics for these hypothetical situations has been made and the phases that occur during these situations are being analyzed.

Session B-13

GRADUATE PROGRAMS IN SCIENCE EDUCATION: THE YEAR 2000 AND BEYOND

James P. Barufaldi
Frank E. Crawley
The University of Texas at Austin
Austin, TX 78712

James A. Shymansky
University of Iowa
Iowa City, IA 52242

William G. Holliday
University of Maryland
College Park, MD 20742

Russell H. Yeany
University of Georgia
Athens, GA 30602

The purpose of this symposium is to describe strengths and weaknesses of four graduate programs in science education. Discussion of each co-author will focus upon the following questions:

1. What is the approximate composition of the graduate program in science education at your institution in terms of coursework in the sciences, science education research supporting work and other professional opportunities?
2. Does the existing program adapt to the needs of the marketplace? If so, how?
3. What social, political and economic issues are affecting the direction of graduate programs in science education?
4. What are the primary needs of a graduate program in science education in the year 2000 and beyond?

In addition, a model will be presented that has been used to evaluate the graduate program in science education at The University of Texas at Austin. Preliminary results and recommendations will be presented and discussed.

Session B-14

A REVIEW OF MEMORY SYSTEMS AND IMPLICATIONS FOR RESEARCH INTO STUDENT QUESTIONING BEHAVIOR IN A SCIENCE SETTING

Marianne B. Betkouski
University of North Florida
Jacksonville, FL 32216

Kathy Conklin
Bishop Kenney High School
Jacksonville, FL 32207

Lehman W. Barnes
Florida State University
Tallahassee, FL 32306

Although developmental, psychological and educational research have provided some bases on which science educators make pedagogical decisions, other interdisciplinary findings emanating out of the cognitive sciences, including neuroscience, need to be considered. Research into how the brain stores and retrieves memories is a useful area to consider when designing research studies and, ultimately, deciding upon educational implications which affect the science classroom teacher. This presentation will document the need for interdisciplinary communication and present a review of memory systems summarized from more than one hundred sources. Sources of data, kinds of memory, memory processing, memory locations, influences on memory, and cellular physiology of memory will be discussed. In addition, an area of research using memory systems findings in its rationale and design will be outlined. Prior interpretive research into children's questioning behavior will be related to memory system findings. These approaches will comprise the infrastructure for suggested research approaches which would be useful to science educators as they accumulate information concerning how students learn science with meaning.

Session B-15

AN EXPLORATORY, CONCERNS-BASED FIELD STUDY OF A TWO-WEEK, SUMMER INSERVICE PROGRAM TO INCREASE SCIENCE TEACHERS' USE OF CHEMICAL DEMONSTRATIONS

Thomas P. O'Brien
University of Maryland
College Park, MD 20742

Henry Heikkinen
University of Northern Colorado
Greeley, CO 80639

An exploratory, field-study approach was used to aid the design, delivery, and evaluation of a science teacher inservice program offered at the University of Maryland - College Park during the summer of 1986. Specifically, the study explored the applicability of the Stages of Concern assessment model to a two-week workshop aimed at increasing science teachers' use of chemical demonstrations (The Institute of Chemical Education's Workshop B: Chemistry Supplements for Pre-High School Classes/Chemistry Can Be Fun Training). Pre-post-delayed post workshop, survey statistics on the use of chemical demonstrations as an instructional strategy and the associated concerns of the teacher-users are reported.

Results of the study to date indicate that the workshop was successful in terms of its ability to attract a diverse group of elementary - secondary science teachers and its ability to mediate an evolution toward impact level concerns and higher self-confidence of teacher participants. The uniqueness of these results is that prior curriculum implementation research based on the Stages of Concern model suggests that the evolution from Self to Task to Impact Concerns among teachers involved with an innovation typically requires a year or more of time and multiple inservice experiences. The present study suggests that, if the innovation is of a more focused, limited nature (such as chemistry demonstration skills), significant growth can occur as a result of inservice designed in light of teacher concerns and educational backgrounds. The success of this particular workshop suggests that this design/evaluation model might prove useful in helping to ameliorate the widely publicized problem of underqualified science teachers. Data documenting the success and difficulties associated with this workshop have implications for other similiar short-term, intensive, skills-oriented inservice programs.

Three-month delayed measures (December 1986) assessed additional changes that occurred as the teachers used newly developed skills in their school-based home environment. Self report data on the use of and confidence with chemical demonstrations both in the classroom and in outreach programs address the viability of the National Science Foundations's reliance on a multiplier effect to spread the impact of a limited number of teacher workshops to a much larger number of teachers.

IMPROVEMENT OF SCIENCE TEACHING OF NATIVE AMERICAN ELEMENTARY STUDENTS THROUGH STAFF DEVELOPMENT: AN ETHNOGRAPHIC STUDY

Deborah R. First
Penn State University
University Park, PA 16802

An ethnographic study of a newly implemented staff development program was conducted in several elementary schools on a reservation. The purpose of the program was to improve science instruction in grades K-8 through the use of a hands-on, inquiry based approach. Research in the last 10 years indicated a positive response to hands-on science in terms of both achievement and problem-solving skills, especially among lower-achieving students. Increased language skills have also been noted. This was an addition to a more traditional text-based program that the teachers practiced.

The rationale for the staff development program was based upon research within the fields of organization/staff development and change theory. The program provided opportunity to link research to current practice, practice materials and centers for classroom use and develop processes for group goal-setting. Work with teachers continued for one week each month for seven months.

The author used ethnographic techniques of participant observation, interviewing and artifact analysis to study the change process. The study illuminates the supports and constraints for change that affected the success of the program implementation. Attention is drawn to factors that determine the form and quality of the curriculum as taught: teacher expectations, adult roles, teacher insularity, student coping skills, group norms, and cultural discontinuities. Conclusions examined are: teachers resist implementing strategies that signal a change in teacher role; the teaching of science is given lip service but does not occur as a regular practice; in the absence of external rewards or pressures to do so, teachers will not implement strategies or curricula that do not provide internal rewards for them; student participation and performance in class is a response to the teacher's hidden curriculum as much as it is to the curriculum in use; students have a positive performance and participation response to hands-on science in class. The use of hands-on science may promote a change in student attitude toward school. Implications for effective implementation of science programs are discussed.

A CASE STUDY OF A K-3 SCIENCE WORKSHOP

Lloyd H. Barrow
Stuart Palonsky
University of Missouri-Columbia
Columbia, MO 65211

A multi-method evaluation was conducted to assess the overall effectiveness of a K-3 summer science workshop program and to suggest modification that would make the program transferable to other sites. The collecting techniques included interviews with teachers and building principals, and participant and instructor evaluations. In addition, pre and posttest comparison were made on science content and various science processes instruments. A variety of data collection strategies reflect interest in the following sources: (1) participant's knowledge of science content processes, and teaching strategies, (2) participant's receptivity toward various presentations, and (3) ability of the program to be of value over time.

During the summer, 1986, 70 hours of instruction covering science processes, science content background as presented by university scientists and master secondary science teachers, and science teaching strategies. The SEARCH model was utilized to formulate the workshop. Each of the 30 participants had to develop mastery of all science process skills by conducting and reporting an individual science investigation.

During the fall, four follow-up sessions will be conducted to provide continued assistance to participants as they facilitate science instruction in their building. About 30% of the participants had a master's degree and 25% were currently working on a M.Ed. About 15% of the participants had not taken course work in the past 10 years. Participants ranged in teaching experience from 5 to 42 years. Only two participants had an extensive science background. More than 65% had less than 12 semester hours in content science and about 20% had no undergraduate science methods course.

The summer workshop resulted in professional growth of the participants. Specifically, there was a 8.1% increase in knowledge on the New Zealand Survey of Some Science-Related Ideas. The pretest scores were very similar to their reported primary teacher responses of New Zealand.

All participants were able to conduct and report their personal science investigation. Participants varied in their ability to develop science curriculum that utilized science processes, especially their questioning strategies. Participants from isolated rural areas were less aware of current science resources such as Science and Children, support material for current science textbooks and children's literature applications and were more unsure of their local science curriculum and its articulation. Overall, the SEARCH model provided the prticipants with what they desired in the workshop.

Session B-16

ASSERTIONS AND ASSUMPTIONS IN SCHOOL SCIENCE TEXTBOOKS

Geoff Giddings
Western Australian Institute of Technology
Bentley, Western Australia 6102

The purpose of this study was to develop a conceptual framework concerning the messages, both explicit and implicit, about the nature and value of science and technology, embodied in secondary science textbooks. An analysis instrument was prepared based upon the conceptual framework and the reliability of the instrument was established. The instrument was then used to analyze selected secondary school science textbooks.

More specific purposes of this study were: (1) to develop a conceptual map for the analysis of the messages about organized science embodied in secondary school science textbooks; (2) to develop an instrument, based on the conceptual map, the Science Textbook Analysis Scheme (STAS), by which these global messages about organized science could be identified and measured; (3) to examine the substantive content of four contemporary secondary school science textbooks to determine the messages about organized science contained therein; (4) to determine the degree to which the messages about science conformed to goals of science education, to views of science held by persons professionally associated with organized science, and to views of science of the general public; and (5) to make recommendations to teachers, curriculum developers and publishers concerning science textbook structure and evaluation.

A content analysis technique derived from a system of analysis of newspaper content was employed. A display analysis to weight the messages according to their degree of prominence was also utilized. The data were analyzed using a modified version of the Janis-Fadner Coefficient of Imbalance.

Samples from four contemporary secondary science textbooks were coded and analyzed for specific biases. Analysis of the textbooks suggested that the STAS was a reliable instrument to determine imbalances in textbook content. The data revealed differences in emphasis between different textbooks and within individual textbooks. Clear imbalances on STAS dimensions were visible in some textbooks. Subsequently, differences between stated goals of science education and textbook emphases were noted.

A PRELIMINARY EXPLORATION OF GRADE FIVE STUDENTS' SCIENCE ACHIEVEMENT AND ABILITY TO READ SCIENCE TEXTBOOKS AS A FUNCTION OF GENDER, READING VOCABULARY, AND READING COMPREHENSION

Larry D. Yore
University of Victoria
Victoria, British Columbia, V8W 2Y2 Canada

Many educators have long assumed that reading ability was directly related to science achievement, that reading plays a major role in science instruction, and that direct instruction on science reading skills would improve science achievement. Furthermore, the interactive-constructive reading model would suggest that prior concrete experiences establish a schema, access prior knowledge and reveal knowledge voids, and focus questions for future reading, thus improving the reading comprehension. One can then suggest that a science instructional strategy that initiates learning with concrete experience, supplemented with textual materials, and mediated with direct instruction on critical science reading skills would discount initial differences in general reading vocabulary and general reading comprehension.

Based on this background, the present pilot study investigated whether an instructional strategy could be designed to overcome initial differences in reading ability of elementary school students. The following questions were explored:

1. Does specific reading vocabulary by reading comprehension interaction exist within the instructional strategy?

2. Can predicted science achievement and science reading differences due to initial reading vocabulary and reading comprehension differences be overcome by a well-designed instructional strategy?

3. Are there gender differences in science achievement and science reading within specific reading vocabulary and reading comprehension levels?

4. Are there interactions of gender and reading ability within the instructional strategy?

The results appear to indicate that general reading vocabulary and reading comprehension make a significant difference in science achievement and in the ability to read science text. Furthermore, the variances observed in boys make the significant contributions to these effects. Little differences in science achievement and science reading ability were related to girls' general reading vocabulary and reading comprehension abilities.

A REAPPRAISAL OF SCIENCE VOCABULARY LOAD PRESENTED IN SECONDARY SCIENCE TEXTBOOKS

Fred H. Groves
University of Colorado
Boulder, CO 80309

The science textbook has too often formed the backbone of the secondary science classroom. Research has shown that over 90% of all science teachers use a textbook 95% of the time. It has also been reported that the number of new vocabulary terms presented in secondary science textbooks is higher than that recommended for junior high and high school foreign language courses. It is believed that this heavy emphasis on science terminology contributes to the generation of negative attitudes toward science, and to lowered attendance in high school science courses.

In this study, certain textbooks that were analyzed in a previous study by R. E. Yager were re-analyzed, taking into account limitations expressed by Yager for the earlier work. Four textbooks were chosen for analysis: PSSC Physics, Biological Science: An Ecological Approach (BSCS "Green"), Modern Chemistry, by Holt, Rinehart and Winston, and Earth Science, by Silver Burdett. Only narrative passages were analyzed, with introductory materials, pictures, charts, graphs, figures, questions, problems, glossaries, indices, appendices and other non-narrative text excluded. The number of pages of narration was determined for each book by counting all pages with less that 1/2 page narration as 1/2 page, and all pages with more than 1/2 page of narration as whole pages, and only pages counted only once, and plurals of words already counted were not included. Every fifth page of narrative was checked. This study produced a noticeable reduction in the vocabulary load estimates as compared to the estimates in the earlier study. Modern Chemistry had the greatest estimate of science terms with 2,950. The BSCS "Green" textbook had 1,899 terms; the PSSC Physics textbook had 1,538 terms; and Earth Science had 992 terms. Except for Earth Science, these are considered to be too high for secondary level science courses, even though these estimates are far lower than those in Yager's study.

It is believed that reducing the vocabulary load of science textbooks will help produce a more positive attitude toward science in the secondary schools. However, such action will not solve this problem. The orientation toward scientific terms and definitions held by science teachers must also be changed in order for true progress to be made toward the changing of attitudes of secondary students toward science and science courses.

DESIGNING THE NUCLEAR ENERGY ATTITUDE SCALE

Lawrence Calhoun
Slippery Rock University
Slippery Rock, PA 16057

Robert Shrigley
The Pennsylvania State University
University Park, PA 16801

Dennis Showers
State University at Geneseo
Geneseo, NY 14454

The purpose of this study was to design a valid and reliable Likert-type scale to test the attitudes of subjects toward the generation of electricity from nuclear energy. More specifically, the steps of this study were the following:

From criteria generated by the sociopsychological and measurement literature, and the Abdel-Gaid model, the measurement principles were applied to a pool of trial items written and pilot-tested on a small population for the purpose of selecting a smaller and more manageable pool of items that could be submitted to a much larger and more diverse population. Using data generated by 829 subjects, a long form and a short form were designed to be used to test the attitudes of subject toward the generation of electricity from nuclear energy.

The 20-item pool represented the domain: attitudes toward the use of nuclear energy to generate electricity. The six subcomponents representing the universe of this attitude object were judged by two juries of experts. Factor analysis did not clearly support the six subcomponents. With some exceptions, this test did factor out two subcomponents (usefulness and safety) that seem to be reasonable content for a nuclear attitude scale.

The evaluative quality of the scale was borne out by the distribution of data on each of the 20 items across Likert's five points, suggesting limited skewness as indicated by their means, standard deviations and percent of neutral responses.

The scale is reliable and homogenous as indicated by (1) a coefficient alpha of 0.93, (2) positive inter-item correlations ranging from 0.15 to 0.73, and (3) adjusted item-total correlations ranging from 0.46 to 0.80.

The scale passed three tests proposed to evaluate construct validity: (1) subjects living further from nuclear power plants generated higher mean scores than those living closer, (2) nuclear engineering students scored higher than an anti-nuclear citizens' action group, and (3) males scored higher than females.

The six items of the short form were drawn from the 20-item pool, therefore some of its tests for validation are embedded within the long form. The short form (1) represents the six subcomponents of nuclear attitudes, (2) has a coefficient alpha of 0.82 despite its brevity, (3) has positive inter-item correlations ranging from 0.23 to 0.69, and (4) has adjusted item-total correlations ranging from 0.51 to 0.72. And, finally, the correlation of the long and short forms generated an r-value of 0.95, suggesting a high degree of relatedness between the two forms. Such data suggest that the short form can be used in attitude research.

Both forms of the nuclear attitude scale are recommended to test treatment effects on groups of subjects of the types represented in this study. The short form would be more convenient for telephone surveys or where a nuclear attitude scale is part of a battery of tests and where time is limited.

Both forms should be normed with other groups of adults, and with intermediate grade and junior high students. Factor and Likert analyses should be continued and divergent and convergent validity tested.

CREDIBLE COMMUNICATIONS AND PERSUADING GIRLS TO TAKE ELECTIVE PHYSICAL SCIENCE COURSES IN HIGH SCHOOL

Thomas R. Koballa, Jr.
The University of Texas at Austin
Austin, TX 78712

Eighth grade girls (N=257) randomly selected from nine different public junior high schools were questioned in order to (1) identify the communicators whom junior high school age girls perceive as credible regarding reasons for taking elective physical science courses (e.g., physical science, chemistry, and physics) in high school, (2) determine if ethnicity is related to their choices of credible communicators, and (3) identify the attributes associated with these communicators.

Four persons were each identified by better than 10 percent of the sample as being the best person to try to convince junior high school girls to take elective physical science courses in high school. In order of perceived credibility, these persons are father, woman science teacher, mother, and boy high school student.

When the responses from the girls of different ethnic groups were examined separately, some variations in the order of perceived credibility were found. Among Hispanic and Black girls, mothers were rated most often as the credible communicator. Boy junior high school students were also considered credible by better than 10 percent of the Black girls. Anglo girls identified women science teachers most often, followed closely by fathers as the most credible source. Nearly half of the Asian girls identified their fathers as the most credible communicator with regard to taking elective physical science courses in high school.

Statements listed for each person identified by better than 10 percent of the total sample (i.e., father, woman science teacher, mother, boy high school student) were examined and classified into the categories of prestige, trustworthiness, similarity, attractiveness, power, and miscellaneous. Better than 40 percent of the statements written for the father and 35 percent written for the woman science teacher were related to prestige. Statements pertaining to mothers were most often placed in the categories of trustworthiness (44 percent) and similarity (20 percent). In addition, 59 percent of the statements written for boy high school students were related to attractiveness. Few statements were placed in the categories of power and miscellaneous.

Finding that father, mother, and woman science teacher are perceived as credible by the girls regarding the taking of elective physical science courses in high school is not totally unexpected. Somewhat surprising is the finding that boy high school students are rated as the most credible communicator by better than 10 percent of the sample. Questioned is the assumption that women considered appropriate role models for adolescent girls in science (i.e., high school girls, graduate women in science, and women scientists) are the best persons to attempt to persuade them to enroll in physical science courses in high school.

COSTA RICAN TEACHERS' ATTITUDE TOWARD SCIENCE AND SCIENCE TEACHING AND ITS RELATIONSHIP TO SELECTED VARIABLES

Juan Manuel Esquivel Alfaro
Universidad de Costa Rica
San Pedro De Montes De Oca, Costa Rica

The purpose of this study was to report the results of the administration of a Likert-type inventory to measure attitude toward Science and Science Teaching to a sample of elementary and secondary science teachers in Costa Rica. The data were also analyzed considering selected teacher variables: tenure, gender, region of the country where the teachers were teaching, and their educational background.

The "Inventario para medir actitud hacia la Ciencia y su Ensenanza" (Attitude toward Science and Science Teaching Inventory) was used. There is good evidence of the content and construct validity of the instrument. Reliability measured by the test-retest paradigm was 0.84. All but one of the sixteen sub-scales of the inventory have Cronbach's alpha indexes between 0.70-0.99. The instrument is divided in two parts. The first one comprises five scales. Each scale has two sub-scales with five items in each one. This first part measures attitude toward science, with a total of 50 items. The second part has three scales, with two sub-scales for each one also. Thirty items composed this second part which measures attitude toward science teaching.

A total of 113 elementary teachers and 115 secondary science teachers answered the inventory. These teachers belonged to elementary and secondary public high schools randomly selected.

Results indicated that elementary school teachers significantly differ from secondary science teachers in their attitude as measured by four of the eight scales of the inventory. In general, however, the attitude toward Science and Science Teaching is positive for both groups of teachers.

No differences in attitude were found according to gender for the elementary and secondary teachers. There were differences by region of work for the group of the secondary science teachers. When the comparison is made between tenured and non-tenured teachers, no differences were found in the attitude of elementary teachers. Tenured secondary science teachers had a significantly higher attitude than the non-tenured teachers on two of the eight scales of the inventory. Finally, comparisons of the attitude of the teachers were made according to their educational background. There were significant differences only for the elementary teachers group, in favor of the non-degree sub-group.

A COMPARISON OF ORAL AND WRITTEN CHANNELS OF PERSUASIVE COMMUNICATION IN THE CHANGE OF ATTITUDES TOWARD TEACHING SCIENCE IN THE ELEMENTARY SCHOOL

Susan C. Demers
Robert L. Shrigley
The Pennsylvania State University
State College, PA 16801

This study investigated the effect of two channels of communication on positive attitude change in preservice elementary teachers toward teaching science. A written communication and an oral (videotape) communication were used to change the attitude of preservice elementary teachers. In addition, subjects were separated into high and low attitude groups after pretesting and were compared.

This study was based on Hovland's persuasive communication model for attitude change. In persuasive communications arguments, fact presentations, conclusion drawing, and future prediction are vital. This approach purports that man will respond rationally to formal communications.

Two analyses of variance for repeated measures were conducted. The first analyzed the difference between channels of communication, and the second analyzed the gain of attitude between low and high attitude subjects in each channel.

A science attitude scale was administered as the pretest, posttest, and retention test. This scale measured preservice teachers' attitudes toward teaching science.

Sixty-six preservice elementary teachers enrolled in a science education methods course were administered the attitude scale on the first day of the semester. Then subjects were randomly assigned to either the written or the oral treatment group. Six weeks later the posttest was given following the treatment. Three weeks later the retention test was administered.

In the oral treatment there was an increase in attitude from pretest to posttest, and the positive attitude persisted from posttest to retention test. In the written treatment there was no difference in attitude change from pretest to posttest, but there was an increase of positive attitude change from posttest to retention test. In both treatments there was no difference between posttest mean scores, and there was no difference between retention test mean scores of the two treatments. The low attitude group generated significantly higher mean scores than the high attitude group in each treatment and at retention testing both low and high groups retained the attitude gain.

Session 8-18

FOLLOWUP STUDY OF THE CONCERNS OF TEXAS SCIENCE TEACHERS ABOUT THE FORTY PERCENT LAB TIME RULE

Robert K. James
Texas A&M University
College Station, TX 77843

In response to the mandates of the Texas Legislature and the State Board of Education, the Texas Education Agency began in Fall, 1985, enforcing an existant rule that 40% of science teaching time in grades 7-12 be allocated to laboratory instruction. Knowledge of the concerns of Texas science teachers about the 40% lab time rule would be helpful in understanding how the implementation of the rule might be accomplished. Initial concerns data were collected in April, 1985, in order to establish baseline data prior to the September, 1985 implementation.

The purpose of this study was to determine the concerns of Texas science teachers about the 40% lab time rule at the end of its first year of implementation and to compare those results with the concerns of science teachers one year earlier.

The Stages of Concern Questionnaire (SOCQ) were sent to a random sample of 400 secondary science teachers. Mailing labels were provided by the Texas Education Agency. In all, 68% of the instruments were returned.

The results for the SOCQ show the following significant points:

1. Personal concerns are most intense, indicating that the teachers are concerned about the impact of this rule on them.

2. The fact that personal concerns are higher than informational concerns suggests that providing information is not desired by teachers.

3. Refocusing concerns, Stage 6, are higher than would be expected, suggesting that teachers believe they have knowledge of alternatives that would work better.

4. Finding this pattern of personal, informational and refocusing concerns suggests that teachers hold a high degree of agitation about the rule. They have better ideas as to how they should use learning time.

5. Typical of teachers whose profiles reflect this view is the result for Stage 4, consequence, which shows that the teachers are much less concerned about the impact of the 40% lab time rule on students than they are on the impact on themselves.

By way of a general interpretation, it can be said that the high personal concerns indicate an uneasiness with the 40% lab time rule. Teachers were concerned about the effect this rule will have on them personally. Since personal concerns exceeded informational concerns, it is probable that they feel negative toward the rule and generally are not open to information about it. This conclusion is corroborated by the unusually high refocusing concerns which, when interpreted in the light of the rest of the profile, suggest that these teachers have ideas about how to do things differently.

The concerns data for a similar random sample of Texas science teachers were collected 12 months earlier. The profiles are very similar with the differences being less than 10 percentile points. In general it can be said that personal concerns have not been resolved after a year, and that much work is to be done if the maturing of concerns to the impact stage is to be achieved.

PERFORMANCE-BASED INSTRUCTION AND TESTING AS A CONSTRAINT IN LEARNING SCIENCE

Terry L. Wood
Purdue University
West Lafayette, IN 47907

The purpose of the present study was to examine the effect of a state mandated policy, emphasizing performance-based instruction and student achievement as the basis for determining school accreditation, on teachers and their instruction of science. The intended consequence of instigating this policy was to improve the current level of student literacy. However, three unintended consequences were predicted: that teachers defined science learning as scores on tests, that instructional procedures would be limited to those which influenced learning tested skills, and that the structure of science lessons would constrain students' opportunities to develop scientific thinking. One hundred and sixty-five seventh grade science students and four teachers participated in the study. Interview questions were asked of the teachers regarding their goals of instruction, teaching behavior and structure of lessons. Classes were observed in order to provide documentation about teaching behavior and lesson structure. Results supported the predicted unintended consequences of the state mandated policy. The teachers exhibited standardized routine teaching behaviors that emphasized learning specific facts for tests. No variation existed in pace of instruction or content coverage between the teachers. Each teacher used the same procedure for predictable procedure of question-asking utilizing only the questions from the student study sheets. The teacher-directed question-asking provided a structure for classroom iteraction that inhibited students from asking questions that were elaborations of the study questions or were questions of their own. As a result, students' opportunity to express curiosity and inquiry, central processes in scientific thinking, were constrained. These unintended consequences of the implemented state policy, instead of improving science teaching and learning, continues to reduce science instruction to the literal comprehension of isolated facts and skills.

SCIENCE AND MATHEMATICS EDUCATION LEADERSHIP PROGRAM: A CASE STUDY

Michael J. Brody
Warren Tomkiewicz
University of Maine
Orono, ME 04469

This project provided training in the areas of leadership, content updates and modern teaching and learning strategies for science and mathematics teachers from public schools throughout Maine. Thirty-five teachers were selected to participate in a three-week summer institute based on their perceived abilities to communicate new ideas within their local education agencies and their commitment to education in the future. Analysis of their personality types according to the Myers-Briggs Type instrument indicates they have the potential to be future leaders in their local districts.

Based on the summer program at the University of Maine, participants returned to their local school districts and conducted inservice workshops incorporating the topics presented in the summer institute. These included content updates in the areas of molecular biology, radiation, marine science, forestry, food science and engineering, as well as the interaction of science and mathematics, working with groups, and computer applications in science and mathematics.

An extensive evaluation of this program was conducted by a team of researchers as part of the programmatic research thrust in the science education department at the University of Maine. Among the criteria evaluated are: (1) the effect of the summer institute on the implementation of new teaching strategies and content areas, (2) the effect of the program on students in selected classrooms throughout the state, and (3) the effect of teacher personality type on the success of this program at the local level.

THE PENNSYLVANIA SCIENCE TEACHING NEEDS ASSESSMENT AND ITS IMPLICATIONS FOR SCIENCE EDUCATORS

David B. Klindienst
Peter M. Mecca
H. Seymour Fowler
Pennsylvania State University
University Park, PA 16802

Recent national attention in science eduction has resulted in many states trying to assess their needs with respect to this curriculum area. Following analysis of data observed from these studies, training programs in science education for preservice and practicing teachers have been established. In Pennsylvania, such a program of assessment and development of prescriptive programs at district or regionals levels has been coordinated through a joint effort of the Center for Education - Science, Technology and Society (CE-STS) at Pennsylvania State University, and the Pennsylvania Science Teaching Enrichment Program (PA-STEP) at Clarion (PA) University. Elementary and secondary teachers from 85 private and public school districts, serving small rural to large metropolitan populations across the Commonwealth, participated in a needs assessment study. Teachers indicated their perceived needs in science teaching and the degree of emphasis these needs should receive in the classroom. These data allowed the investigators to identify new or previously unmet needs. Programs in science education for teachers were then developed at the district and regional levels. Further, the data were shared with participating districts for their use in science curriculum and staff development.

The investigators will discuss the development and administration of the needs assessment instruments, will summarize the data, will describe how the data were used to implement programs which address specific needs, and will explore the implications of this study for the future role of science education. Comparison of data from this study and research reports related to elementary and secondary science teaching will be included in the discussion.

Session B-19

SECONDARY SCIENCE TEACHERS' PERCEPTIONS OF THEIR OWN CLASSROOM PERFORMANCE

James Gallagher
David Cline
Michigan State University
East Lansing, MI 48824

A two-year study of science teaching in five secondary schools showed a discrepancy between teaching performance of qualified experienced science teachers and expectancies of university-based observers. This study was designed to examine teachers' perceptions of the quality and effectiveness of their own classroom performance and to identify factors which contributed to these perceptions. More specifically, three research questions were asked:

1. How do secondary science teachers perceive the quality of their classroom performance, given the discrepancy in quality between their apparent potential and actual delivery of instruction?

2. On what basis do teachers evaluate the quality of their own performance?

3. What factors contribute to differences between classroom teachers' and university researchers' perceptions of quality classroom performance?

Ethnographic methods, including classroom observations, informal conversations, and formal interviews were used to study self-appraisal of teaching performance of 27 experienced, qualified middle and high school science teachers. Data were also gathered regarding the basis of their self-appraisals and factors which contributed to discrepancies between their self-appraisals and judgments of quality made by observers.

Results showed that nearly all teachers were very positive in their appraisals of the quality and effectiveness of their own work. When presented with conflicting data, such as evidence of low engagement of students during instructional tasks and the small amount of attention which they gave to poorly motivated students, one of two responses were given: Teachers either denied the accuracy of the data, saying that on days that observers were not present student engagement was higher and they called on students that had not been engaged during our observations; or they dismissed the observation as not important by saying, "the interested and motivated students will learn and the others will not."

At first, this response was interpreted as a means by which teachers abdicated their responsibility for teaching all but the more motivated students. However, it became apparent that this statement indicated their perceptions of professional responsibility. When coupled with data from other parts of this study which showed that teachers perceived their role to include presentation of scientific content and organization of instructional activities and environments that allow students to learn it, it became apparent that secondary science teachers are not concerned with students' learning. They limit their role to presenting information and organizing instruction. Learning is the students' responsibility. Teachers do not see their role as including diagnosis of factors which underlie difficulties that students encounter in learning subject matter, nor do they include remediation as part of their instructional responsibility. Factors which contribute to this viewpoint relate to both role perception and limitations of skills to conduct diagnostic and remedial activities with students.

These results suggest that teacher educators and supervisors of secondary science teachers should give more attention to definition and clarification of the role of secondary science teachers as part of both preservice and inservice education. Moreover, more work is needed as part of teacher education to assist in developing diagnostic and remedial skills as part of the repertoire of secondary science teachers.

A CHANGE IN THE SCIENCE CURRICULUM: STUDENTS' NEEDS OR TEACHERS' EASE?

David A. Cline
Michigan State University
East Lansing, MI 48824

This is a report of a case study of a high school that changed its science requirement for graduation from one year to two years of science. After the implementation of the new requirement, the high school introduced a new course of study. After the course was in place for two years, the class was found to be not meeting the needs of the population it was intended to serve. With the assistance of a large university, a grant was secured that provided for the development of a new science class for the less able, less motivated, and less interested student. This paper traces the development of that new course.

The main focus of the paper is on a group of high school teachers and their development of a curriculum for a lower-level science class to meet the needs of students of lesser ability, interest and motivation. These purposes imply the need for descriptions of behavior and investigation of what lies behind the behavior. Due to the nature of the questions asked, the approach being used is ethnographic. The principal investigator has regularly visited the school to observe secondary science classes and discuss organization, content decisions, teaching strategies, and other choices made by teachers, department heads, and administrators. Informal meetings and formal interviews with school staff members were also part of the planned procedures for data collection. Review of texts, other instructional resources, tests, and policy documents was another important data source as well as participant-observation by the researcher who worked with teachers and department heads in classrooms, laboratories, teacher workshops, and planning meetings.

This report also examines three findings of the study: (1) the teachers' perceptions of the lower ability, interest and motivation students in the science class, (2) a comparison of what the teachers say that these students need to learn and what is actually taught, and (3) an attempt to understand the teachers' actions when examined in the culture of the school.

CONTINUING PROFESSIONAL DEVELOPMENT ACTIVITIES OF SECONDARY SCHOOL SCIENCE TEACHERS

Okhee Lee
James J. Gallagher
Michigan State University
East Lansing, MI 48824

Professional growth activities of 35 secondary science teachers were investigated as part of a larger study which involved 7 schools in 3 midwestern communities. The teachers involved in this study were well-qualified and had a strong experiential background, averaging 18 years as science teachers. Most held advanced degrees which were about equally divided in specialization between science disciplines and education.

Data were acquired largely through informal conversations and formal interviews held over a period of several months in conjunction with classroom observations. In addition, information regarding prospective secondary science teachers' perceptions of the character and potential utility of specific science education journals was included in this study. These data were acquired from written analyses of familiar journals prepared as an assignment for a secondary science teaching methods course.

Data from interviews, informal conversations, and classroom observations showed that:

1. The secondary science teachers studied devoted little time to professional development activities. They did not engage in professional meetings on a regular basis. They did not value school-based inservice programs, nor did they engage systematically in reading, coursework, or other expected forms of professional development activity.

2. Few secondary science teachers utilized findings from educational research and development in their classes.

3. Few secondary science teachers read pedagogical or scientific literature systematically or with regularity. However, a small portion of the teachers studied did read widely and systematically.

4. Teachers had limited access to professional journals of either a scientific or a pedagogical character. Journals dealing with science, its applications, or pedagogy were not found, generally, in science rooms, school professional libraries, and only a few teachers subscribed to professional journals personally. Only one of the teachers utilized the facilities of an adjacent university library as a resource for professional growth.

5. Of the 35 teachers studied, only one regularly attended national or international meetings; and his interests and attendance had shifted to computer applications in science. About half of the teachers participated in the state science teachers meeting which extended for one and one half days each year. However, none of the teachers in the seven schools could be considered as active participants in professional organizations.

6. Television programs, such as "Nova," "National Geographic Specials," and Jacques Cousteau's specials, constituted a major source of information about new scientific developments and their applications for these teachers. No pedadogical counterpart was noted.

7. Prior to the assignment to review science education journals in their methods course, prospective secondary science teachers, who were at junior level or higher in college, had no knowledge of the existence of a professional literature in science education. Moreover, they had limited experience with the literature of science, and professional reading was not part of their values set in either science or education.

The implications of these findings for science educators and for scientists engaged in teacher preparation are serious. These data show that most prospective and experienced teachers place little value on continuing professional development as a part of their professional responsibility. Moreover, practicing teachers do not acquire new information about science, its applications, or pedagogy systematically or at a rate that even remotely keeps them abreast of new developments and changes. It would appear that efforts need to be made as part of teacher education programs, in both science and science education courses, to foster the values, knowledge and skills needed for continuing professional development.

DIFFERENTIAL TREATMENT OF STUDENTS BY MIDDLE SCHOOL SCIENCE TEACHERS: UNINTENDED CULTURAL BIAS

Armando Contreras
Okhee Lee
Michigan State University
East Lansing, MI 48824

The general question addressed in this study is to describe how middle school science teachers differentially treated ethnically mixed classes in tacit manners in the context of everyday school activities. The nature of this question suggested an ethnographic approach which allowed description of behavior and investigation of what lies behind observed events. The data sources included classroom observations; interviews with teachers, students, and administrators; videotapes of classes; and instructional materials and school documents. Three middle school science teachers who taught "enriched" classes of highest achieving students and other non-enriched classes participated in this study.

The analyses of data sources reveal degrees of variation among the teachers with respect to their awareness of cultural differences and their subsequent treatment of different ethnic groups of students. Two teachers differentially treated students by providing more opportunities for learning to enriched class students while covertly restricting access to the same opportunities for non-enriched class students. This pattern of differential treatment was observed in the context of everyday teaching and interactions with students during classes as well as outdoor science activities. The third teacher, in contrast, manifested positive attitudes toward students by providing an environment that led most students from both groups to participate in learning activities and interactions with the teacher.

This study reveals the existence of a set of norms and social values that delimit a high percentage of minority students, expecially in non-enriched classes, from actively participating in learning experiences in and outside classrooms. The findings imply the importance of developing proper mechanisms to deal with cultural bias as a way to cope with miscommunications between teachers and students partly due to racial and ethnic differences.

AN ETHNOGRAPHIC STUDY OF HIGH SCHOOL PHYSICS LABORATORY EXPERIMENTS

Ribhi Abu Isneineh
Armando Contreras
Michigan State University
East Lansing, MI 48824

Recent science curriculum development has always stressed the significance of laboratory activities. However, various aspects of these activities have not received adequate attention from researchers. This study focuses on a major category of these activities, namely, physics experiments. It describes the planning and execution of high school physics experiments. It also describes the roles undertaken by the teachers and students in this process.

Four experienced high school physics teachers participated in the study. These teachers are working at three different schools in the midwest. Participant observation over a period of one year for class discussions as well as lab activities has been carried out by the two researchers. Field notes collected during observation as well as transcripts of audio-recordings of lab proceedings and interviews are the major sources of data of the study. Analysis of data was done within the traditional ethnographic techniques. Findings show important variations among teachers in the way they carry out these experiments. While some teachers emphasize aspects of verification and simple deductive reasoning, others tend to teach inductive reasoning.

Roles undertaken by teachers as well as by students vary widely. While some teachers tend to act as merely facilitators or helpers for students to understand and carry out the procedural steps needed for the experiments, others tend to get involved in a more sophisticated process of reasoning. Student participation also varied in complexity and sophistication.

Implications as well as suggestions for science instruction and science education research are made. Discussions over the effectiveness of physics experiments with teachers may prove very useful. Factors influencing teachers' laboratory practices need to be studied.

Session B-20

A TECHNOLOGY FOR OPERATIONALIZING SCIENCE OBJECTIVES FOR SCIENCE ASSESSMENT

Jeanne Miyasaka
E. Lynn Talton
L. Lynne Mappus
Gayle Killian
South Carolina Department of Education
Columbia, SC 29201

The emergence of the basic skills movement in the 1970's focused much attention on the assessment of basic reading, mathematics and writing skills to make important decisions about student achievement and program effectiveness. As a result, several assessment technologies, including item writing technologies, developed rapidly to meet the needs of the many large-scale state assessment programs. These technologies have been a boon to the assessment of student learning in general because they provide strategies to improve the quality of assessment instruments at the classroom and district levels as well.

In South Carolina, the Education Improvement Act of 1984 amended the Basic Skills Assessment Program Act (BSAP) to include science as a basic skill. This Act mandated the identification of state science objectives for students in grades one through eight and the annual assessment of student achievement with respect to those objectives in grades three, six, and eight. This is consistent with the assessment of reading, mathematics, and writing basic skills. State standards of student science achievement will be established at each testing grade, and the reporting of test results will indicate whether or not each student has met the state standard in science.

There are several reasons why special care and attention have been focused on the development of the South Carolina science objectives and tests. First, because student science achievement will be judged against a state standard, it is critical that the science tests must be both content valid and technically sound. Second, the results of the assessment serve multi-level purposes. While a major purpose of the results is to provide diagnostic information at the student level, the results also provide information for evaluating basic skills science programs at the school, district, and state levels. Finally, because of the limits of test length, the items must be developed to provide maximal information in the most efficient manner.

In this symposium, a science assessment technology will be presented. This technology was developed to increase the linkages between science objectives and science test items. The technology is both significant and unique in several ways. It was developed through close collaboration among staff and consultants who contributed and integrated their science education, cognitive psychology, instructional psychology and measurement expertise. Recently developed assessment technologies from the fields of measurement and science education were combined and adapted, and innovative approaches for assessing different types of science learning emerged. Furthermore, the technology addresses science assessment at a level of specificity which will be both novel and useful to science educators.

This symposium will be composed of three presentations which will describe the major components of the assessment technology. First, procedures for developing a science objectives framework for instruction and assessment will be described. Then, strategies for operationalizing science concept and process skill objectives into multiple-choice item specifications will be presented. Issues, problems, solutions and limitations will also be discussed.

Session B-21

FACTORS INFLUENCING THE SUCCESS OF SCIENCE CURRICULUM IMPLEMENTATION IN MIDDLE SCHOOLS

Linda L. Cronin
University of Florida
Gainesville, FL 32611

Michael J. Padilla
University of Georgia
Athens, GA 30602

Kenneth Tobin
Florida State University
Tallahassee, FL 32306

This study was designed to investigate the factors contributing to the discrepancy between intended and implemented science curricula in middle school classrooms. The first purpose of the study was to identify the factors influencing the success of implementation of a given curriculum. Once these factors were identified, the second purpose of the study was to determine the relationships between these factors in different classroom contexts. In this study, success of curriculum implementation was defined in terms of fidelity of implementation as well as in terms of student outcomes.

Two middle school science teachers and their science students participated in the study. The two teachers successively implemented a prepared 20-lesson environmental education curriculum. Each teacher participated in the study for approximately six weeks, while the entire data collection period spanned 16 weeks.

During the study, both qualitative and quantitative data were collected. Qualitative data included daily field notes, audiotaped teacher and student interviews, and student work files. Quantitative data included formal pre- and post-assessments of student attitudes and content area knowledge relative to the curriculum topics as well as daily quantitative measures of teacher performance.

The data were analyzed using the constant comparison method. Categories of influence were identified and assertions were generated. These categories and their constituent assertions were used to generate a tentative implementation model for the prepared curriculum. The categories of influence were organized hierarchically according to the difficulty associated with changing or manipulating each factor. Nine broad categories of influence were identified: teacher beliefs, teacher knowledge, external factors, student characteristics, teacher expectations, teacher planning, teacher performance, classroom interactions, and student engagement. The categories which were most resistant to change during the course of the study included teacher beliefs and teacher knowledge. The categories most amenable to change or variation during the course of the study included classroom interactions and student engagement.

Although contextual differences were found to significantly influence both the processes and outcomes associated with implementation of the science curriculum used, certain levels of the model appear to be generalizable across diffferent curricula and classroom contexts.

A PROCESS APPROACH TO IMPROVED SCIENCE INSTRUCTION: PRELIMINARY FINDINGS AT THE ELEMENTARY LEVEL

David L. Haury
Tufts University
Medford, MA 02155

Recent calls for reform of school science instruction gave rise to a collaborative program improvement project and this study of its effects. Beyond improving the science program of a particular school district, a major purpose of the project has been to examine a new model of university-school interaction and teacher education. Science educators at the university were seeking direct and regular involvement with schools, and greater opportunity to foster professional growth among practicing teachers. Schools participating in the project were seeking an improved science program tailored to local conditions, and help in providing experiential science lessons.

The project focused on program improvement through professional growth, and has attempted to build on the existing program by moving with gradual steps toward an idealized program. The aim has been to put the power of decision in the hands of those who deliver the instruction, with all others taking a supporting role. Teachers of the study were encouraged to take risks and become actively involved in the process of identifying promising practices.

The study has been ethnographic in nature, with the project director observing and collecting descriptive data. Classroom observations, interviews, surveys, and faculty meetings provided a broad array of data. The collected data seem to indicate that the project has had an educationally significant and positive effect on the K-6 program. An increased willingness to provide experiential science lessons has been accompanied by the piloting of innovative activities, increased acquisition of instructional materials, and increased professional involvement among practicing teachers.

The preliminary results of this study do not permit prescriptive guidelines for university-school projects, but it seems clear that genuine attempts at reform through partnerships can lead to program improvements and professional growth of all participants. It also seems clear that many of the positive results of this project began to occur after an exploratory period during which a working relationship emerged, not unlike the pattern in discovery learning.

AN ANALYSIS OF PARENT, STUDENT AND TEACHER EVALUATION OF AN ELEMENTARY PROCESS-APPROACH CURRICULUM

Pamela Fraser-Abder
The University of the West Indies
St. Augustine, Trinidad, West Indies

Development, implementation and evaluation of the elementary process-approach curriculum involved working with parents, students and teachers. Parents came from a wide range of educational, economic and social backgrounds and were required to be involved as resource persons, providers of some teaching materials, and stimulators of interest in science in their children. The curriculum had to cater to a wide range in intellectual development in any given class, to better prepare students for secondary science and to stimulate and maintain student interest and enjoyment in science. Teachers had a negative attitude to science teaching and a poor science background. On the basis of their involvement in the curriculum process, teachers were divided into three categories.

This study was designed to assess and analyze parent, student and teacher evaluation of specific aspects of the curriculum. Two hundred fifty parents, 700 students and 300 teachers were randomly selected to respond to questionnaires. The parent questionnaire assessed parental involvement, parental perception of student enjoyment, parental opinion of the teaching of science, and parental opinion of the effect of science on the child. The student questionnaire assessed student interest, student enjoyment, student understanding, and student participation. The teacher questionnaire assessed teacher interest in the curriculum, teacher evaluation of the curriculum, difficulties experienced in teaching the programme, usefulness of the teacher's guides, and effectiveness of the implementation strategies.

Analysis of the questionnaires indicate that most parents, students and teachers found the curriculum to be exciting, effective and interesting. Category 1 teachers were most effective in achieving the aims and objectives of the curriculum and in stimulating a positive attitude in their students and parents. However, it is clear that teachers have concerns about science and how to teach science; these concerns are greatest among teachers with a weak science background. It would appear that further future inservice training for teachers is necessary in order to ensure longevity and effectiveness of the science curriculum. The data, however, suggest that the nature of the curriculum allows teachers to present a positive and exciting image of science.

Session B-22

EFFECT OF SURFACE STRUCTURE AND DEEP STRUCTURE ON NOVICE RULES OF PHYSICS

David P. Maloney
Creighton University
Omaha, NE 68178

This study used Siegler's Rule-Assessment technique to investigate how novice students' strategies varied in working task sets that shared either common surface structure or common deep structure. The term "surface structure" is used here to indicate that the task sets in this group all involved the same object, a toy truck. However, the trucks were doing different things (going up an incline, going down one incline and up another, compressing a spring, and pulling up a hanging block) so the physical principle that applied varied among the task sets. In the "deep structure" task sets, the object that was moving varied, but all situations required application of the same procedure to reach a valid decision. Four systems (boats coasting to a stop, moving blocks compressing pistons on gas cylinders, arrows sticking in sand, and moving carts with magnets) were used, although each subject worked only three of the four. The deep structure sets actually contained two subsets. For each of the three different objects involved, subjects were asked both which would take longer to stop and which would go farther before stopping.

All subjects were novices in that they had never had instruction in physics at the college level. Subjects were paid for participating. Preliminary analysis of the data revealed several trends. First, subjects exhibited a strong tendency to use the same rule on most, if not all, task sets in both groups. Second, one rule, the product rule, was the most commonly used rule. Third, one task set, Boats on a Lake, elicited a different pattern of rule usage from the other sets. Finally, these subjects used the same rule for both the time and distance questions on the deep structure sets 77% of the time.

These results indicate several things. First, for these situations at least, students may focus more strongly on the question asked and the variables provided than on the specific objects involved. Second, the concept of momentum, which is what the product rule gives in most of these cases, is a naturally appealing one. And third, these subjects frequently believe that for two objects which are moving the one that travels for the longer time also goes farther. Some instructional implications of these results for teaching kinematics will be proposed.

AN INVESTIGATION OF THE APPLICATION OF TRAINING IN CREATIVE PROBLEM SOLVING TO SCIENTIFIC PROBLEMS

Bonnie Cramond
Edward L. Shaw, Jr.
Southeastern Louisiana University
Hammond, LA 70402

Training in Creative Problem Solving (CPS) is being promoted as a method of helping students to more effectively solve problems with innovative solutions. Although this method has been shown to effectively increase students' performance on measures of creativity and in similar problem solving situations, the degree to which students generalize such a method to solving novel problems presented outside of the context of the training situation is uncertain. The purpose of this study was to determine whether students trained in CPS do, in fact, use that training when confronted with problems of a scientific nature and if the solutions they generate are qualitatively or quantitatively different from those generated by an untrained group.

Preliminary results indicate that there were no differences, while taking a test of science problem solving, between those elementary school students trained in CPS and those not trained in their observable behavior. Nor were there any apparent differences between the groups in the methods used to attack the test problems as reported in individual interviews with the students. Analysis and comparison of the responses of the two groups to items on the test should answer the question of whether CPS training had any effect on the quantity and quality of the responses.

IMPROVING PROBLEM SOLVING IN A STATEWIDE PHYSICS PROGRAM

Maria Varela
Warren Wollman
University of Rochester
Rochester, NY 14627

In New York State, there is currently an effort to upgrade problem solving skills in the statewide (Regents) program. The challenge to curriculum designers is (1) to introduce skills which can be evaluated by a statewide exam subject to the usual constraints (multiple choice, of reasonable difficulty for the average student), and (2) to define the skills clearly enough so that teachers will know what is being asked of students. A working definition has been used to allow the rational construction of ostensibly simple, readily testable problems for use in the early stages of the upgrading effort. Although teachers are encouraged to challenge their classes with richer, more complex problems, the simple ones we have been working with were chosen for our initial attempts to learn how students try to solve them and how they can be helped in their efforts.

Problems were limited to "two-concept" questions that required the assembly of two familiar concepts in an unfamiliar way. Questions asked students to either solve the problem or just describe a strategy for doing so. Only the first problem type is discussed at this time. An additional problematic aspect of the two-concept questions is the proximity of the concepts. We investigated the effects of these two aspects, two concepts vs. one and proximity. Three hundred sixty-five students from 22 physics classes were tested; an additional 30 were interviewed to better understand how they tried to solve the problems and to assess the effects of two kinds of general problem solving hints. The two kinds of hints, called "semantic elaboration" and "procedural" were meant to help students think about the physics of the problems and to consider indirect ways of using formulae to find an unknown.

Both sources of problem difficulty were quite effective in raising error rates for a variety of problems to levels two to three times higher than for corresponding non-problems (one-concept). Error rates ranged from about 30% to 75%. Both kinds of hint were effective, particularly the procedural hints. Thus, the high school students performed more poorly than the college freshman who participated in previous similar studies, but the positive effects of the hints suggest that these problems were not too difficult to learn to handle, especially given the simplicity of the hints. Internalizing the hints would seem to be primarily a matter of practice, of acquiring better habits.

Teachers expressed a desire to teach problem solving, but feared that the crowded syllabus would not allow them the time. Moreover, they said they would take their cue from the statewide exam as far as how much to emphasize problem solving. Currently, it is not at all emphasized. Thus, the exam exerts a powerful influence on teachers' perceptions of the goals of the curriculum. This research describes the beginnings of our efforts to change the exam, and along with it, teachers' goals and practices.

MEASURING CONCEPTUAL UNDERSTANDING IN INTRODUCTORY PHYSICS

William C. Robertson
Colorado College
Colorado Springs, CO 80903

Research on knowledge structures which facilitate understanding in physics problem solving has been limited. However, research in other problem solving domains suggests that understanding comes about through the building of appropriate "connections" between various knowledge components. This study involved the use of protocol analysis (think-aloud verbal reports) to measure whether or not subjects enrolled in introductory college physics possessed a cognitive connection between the equation involved in Newton's Second Law ($\Sigma F=ma$) and the concept of "systems" as it relates to that equation.

Extensive coding schemes were developed to analyze verbal reports which were collected as subjects possessed the aforementioned cognitive connection, and hence an understanding of the "system concept."

This degree of understanding was strongly correlated with subjects' performance on novel Newton's Second Law problems (transfer problems) contained in a written exam. In addition, degree of system concept understanding uniquely accounted for a large percentage of the total variance in subjects' transfer problem solving performance when compared with the predictive power of ACT scores, physics course exams and grades, and performance on familiar problems contained in a written exam. Results also show that the system concept is not well understood by students of introductory physics.

Implications for instruction include a recommendation of stronger emphasis on the system concept -- $\Sigma F=ma$ connection associated with Newton's Second Law. A similar emphasis is suggested for connections between other physics concepts and principles and their attendant ancillary knowledge.

The method of quantitative protocol analysis utilized in the study stands as a promising tool for investigating problem solving behaviors and strategies as well as for investigating the knowledge structures associated with those behaviors and strategies.

MODELING SCIENCE CLASSROOM ENVIRONMENTS WITH LARGE SCALE SURVEY DATA: AN ANALYSIS OF THE IEA NINTH GRADE SAMPLE

Michael A. Dryden
Arizona State University
Tempe, AZ 85287

Using student and teacher data from the U.S. ninth grade sample of the 1983 International Association for the Evaluation of Educational Achievement (IEA), a structural model for process-oriented classroom interactions was hypothesized and tested. A priori scales were tested with principal components analysis. Reliabilities of the slightly modified scales were reported and used as manifest variables in the latent variable structural model. The latent variable structural model was tested using the partial least squares (PLS) method. Results showed that ability and home background factors have the largest effect on student achievement. Females have more positive attitudes toward school, but males have more positive attitudes toward science. Girls found science more difficult, and boys found science more interesting. Father's education and the number of books in the home were the best indicators of student home background variables. It was also shown that the amount of process environment also had a significant impact on student achievement. Attempts to directly correlate teacher background variables with student achievement failed, and only indirect effects mediated through the process oriented environment were found. Due to the clustered nature of the sample, standard errors of latent variable path coefficients were found using jack-knife repeated replications.

SCIENCE EDUCATION FOR NATIVE AMERICANS: SCHOOL ENVIRONMENTS

Frances Lawrenz
University of Minnesota
Minneapolis, MN 55455

Heather McCreath
Arizona State University
Tempe, AZ 85287

The current crisis in science education is particularly difficult for minorities, especially Native Americans. Native Americans are the most underrepresented minority in the scientific and technical professions. Only a few Native Americans go on to college and, if they do, they are unlikely to choose science majors. This reluctance to enter science fields could be caused by a variety of factors, but precollege science experiences have been targeted as a major contributing factor. Although the precollege classroom environment

has been shown to be consistently related to science outcomes, little information is available about Native American school environments. This study presents the results of a quantitative and qualitative data-gathering effort designed to describe the environments that exist in Southwestern United States' schools serving predominantly Native American populations. Information was obtained through the use of interview protocols and observation schedules during site visits and through the use of two mail survey instruments. These descriptions provide insight into the dynamics of these schools and provide a basis for identifying areas where interventions might result in the improvement of Native American involvement in the sciences.

The data showed that the environments were quite favorable and similar to those in schools throughout the Southwest. The teachers were well educated, were experienced in the classroom, and were open to curricular innovation. Times spent teaching science were consistent with general patterns, and science was presented at least sometimes in a hands-on, concrete fashion. There appears to be three areas where the environments of the schools serving predominantly Native Americans differ from the environments of other schools in the Southwest. One is the diversity of science curricula; second is the high turnover in teachers at a given school; and third is the lack of communication both within and between schools. These three areas should prove fruitful in the search for variables that are causally related to Native American involvement in science.

INTERACTION BETWEEN EXAMINATION TYPE, ANXIETY STATE, AND ACADEMIC ACHIEVEMENT IN COLLEGE SCIENCE

Uri Zoller
D. Ben-Chaim
Haifa University - Oranim
Tivon, Israel 36910

The trait anxiety profile of future science teachers, as well as their preferences concerning types of examinations in science and mathematics, were surveyed prior to the administration -- within the various science courses -- of several traditional and non-traditional types of examinations and the assessment of students' state anxieties as well as their respective performance, i.e., their academic achievements. Major findings are that:

1. Our students prefer, by far, examinations in which the emphasis is on understanding and analyzing rather than on knowing and "remembering"; that the use of any relevant material during the examinations be permitted; and that the time duration be practically unlimited (e.g., "take home"-type examinations).

2. Students' state anxiety correlates with the type of the examination, with a tendency towards somewhat higher anxiety for females. The preferred types of examinations reduce test-anxiety significantly, and improve performance accordingly.

3. The reduction of anxiety and the improvement in achievements as a function of the examination type are far more significant for poor achievers compared with medium and high achievers.

4. Although teachers are aware of the student preferences, they persist in giving their students their own "pet"-type examinations.

These results are discussed in terms of the implications for upgrading both science education and college student assessment mechanisms.

Session B-24

PREDICTIVE VALIDITY OF GPA, CAT AND NTE SPECIALTY TESTS ON SCORES OF A PERFORMANCE-BASED STUDENT TEACHING EVALUATION INSTRUMENT

Roger G. Olstad
Andrea V. Marrett
University of Washington
Seattle, WA 98195

The purpose of this study was to determine whether grade point average (GPA), the California Achievement Test of Basic Skills (CAT), and the National Teachers Exams Specialty Tests (NTE) for Chemistry, Physics and General Science and for Biology and General Science predict student teaching competence as measured by a performance-based assessment instrument.

The issues of teacher quality expressed by many of the national reports on excellence in education have led a number of universities and colleges to increase the admission requirements and/or the exit standards for teacher certification programs. Emphasis has been placed on higher grade points and demonstrated academic ability on national standardized tests.

An assumption exists that each of these measures (GPA, CAT, and NTE Specialty Tests) may be viewed as a continuum. The students score according to their capability, and the value of their score in some way reflects their competence for teaching.

The question is whether the objective measures used to control entry into student teaching (such as GPA and standardized tests) have any predictive relationship with the ability to teach.

Data from this study show mean scores for GPA, CAT, and NTE Biology and General Science, and Chemistry, Physics and General Science Tests at 3.23, 220, and 737 and 678 respectively. These scores compare to admission criteria minimums of 3.03 for GPA and 200 for CAT. The NTE scores compare to national scaled scores of 87% and 84% respectively. The summed evaluation score averaged 47 points out of a possible 55. The range of evaluation scores was 32.5 to 55.

A linear regression was computed for each of the variables. No significant relationships were found for GPA and the final relationship found between either CAT or NTE Biology and General Science Test scores and the final student teaching evaluation scores. There was however, a negative relationship ($r = -.69$, $p. = .06$) between the final student teaching evaluation and the scores on the Chemistry, Physics and General Science exam.

Considerable emphasis is being placed on academic competence of teachers as a means to achieve excellence in the schools. As demonstrated in this study, academic rigor established through high GPA and national standardized test scores leads to narrow variance in performance scores of student teachers. When academic admission standards are high, the variance in performance of student teachers is insufficient to allow prediction to occur.

A second consideration of this study is the use of a Likert-type final evaluation. The Likert-type scale for the final evaluation may allow subjective feelings to influence the final scores.

A COMPARATIVE ANALYSIS OF NOSS PROFILES ON NIGERIAN AND AMERICAN PRE-SERVICE SECONDARY SCIENCE TEACHERS

William W. Cobern
Austin College
Sherman, TX 75090

In this study, American pre-service science teachers' responses on Kimball's Nature of Science Survey (NOSS) were used as a basis for analyzing the sense of the nature of science held by a group of Nigerian pre-service science teachers. From an item by item comparison, two salient differences were noted. These differences are quite interesting and important and one would expect to see replication attempts in the near future.

The primary difference was that the Nigerian students were much more inclined to see science as a way of producing useful technology. Given the national interests of a developing nation this is an understandable perception as well as a perception held by many government policy makers. Nevertheless, it is a view with potential long-range dangers if this view of science is effectively transferred from teacher to student. For example such a view is likely to raise false expectations in the general population which, when not achieved, could result in widespread rejection of science.

The second distinctive of the Nigerian students' sense of the nature of science had to do with the openness of science. These students perceived scientists as nationalistic and secretive about their work. This finding is troubling and indicates an important line of investigation: What is the image of science, especially Western science, that is carried in the international media? How is that image understood in non-western nations? and, What are the implications for international scientific cooperation?

INFLUENCING PRESERVICE ELEMENTARY TEACHERS' VIEWS OF SCIENCE THROUGH FILMS

Betty Crocker
Southern Oregon State College
Ashland, OR 97520

Joseph P. Riley, II
University of Georgia
Athens, GA 30602

Previous research has indicated that preservice elementary teachers hold a view of science that differs from that held by members of the science community. In general, preservice teachers view science in a less tentative manner. This more rigid view may influence the way in which these teachers portray science and communicate it to their students. This research study evaluated the efficacy of film mediation in altering the preservice teachers' view of the nature of science. Films from two widely distributed film series were evaluated. Subjects were randomly assigned to treatment sessions in a Soloman four-group design. Results indicated that some films can influence preservice teachers' view of science.

The nature of the treatments make it possible for science educators to make use of the treatment in their classes and expect similar results.

Session C-1

MICROCOMPUTER-BASED LABORATORIES

Joanne S. Stein
Rafi Nachmias
Yael Friedler
University of California-Berkeley
Berkeley, CA 94720

John Layman
University of Maryland
College Park, MD 20742

Janice R. Mokros
Deborah L. Levine
Technical Education Research Center
Cambridge, MA 00202

Microcomputer-based Laboratories (MBL) constitute a new class of technology allowing students to use the computer much as research scientists do: to collect, record, and manipulate data. As such, this emergent technology would seem to have great potential for science teaching. In the past year, several research projects have examined that potential from a variety of perspectives, using the MBL hardware and software developed by the Technical Education Research Centers (TERC). This symposium will present results of that research.

Yael Friedler and Rafi Nachmias, in "Fostering Scientific Reasoning Skills as a Consequence of Using MBL", will report on the results of an intervention to increase students' ability to make valid observations and predictions in an MBL environment.

John Layman will discuss MBL implementation from the teacher's perspective in his paper, "Microcomputer-based Laboratories: Questions and Consequences for Teachers".

Janice R. Mokros and Deborah L. Levine, in their paper, "The Use and Impact of MBL as a Function of Learner Characteristics" will examine differences in MBL use and learning outcomes for students grouped by ability into different classroom environments.

Rafi Nachmias and Yael Friedler will examine "Students' Perspective on the Validity of Computer-Presented Graphs in an MBL Environment". In this study, students who used MBL regularly were asked to critically evaluate MBL graphs to discover the propensity for students to accept incorrect graphs as valid, and to determine to what extent students understood the causes and remedies for incorrect graphs.

Joanne Stein and Rafi Nachmias' paper "The Computer as Lab Partner Project: Students' Subject-Matter Achievements", reports on the learning of science topics which occurred during administration of an MBL curriculum developed by the Computer as Lab Partner Project. This project set up a computer-equipped science laboratory to evaluate MBL use in eighth grade physical science classes.

Session C-2

ISSUES IN TEACHER EVALUATION

William Capie
Pamela Sloan
Chao Ti Hsiung
Zurida Ismail
University of Georgia
Athens, GA 30602

William Capie will present an introduction to the session including a description of the context and data collection.

The second presentation "A Comparison Between Quantitative and Qualitative Data: Implications for Teacher Evaluation" will be made by Pamela Sloan.

The third presentation "The Relationship Between Experienced Teacher Planning and the Quality of Instruction: Implications for Teacher Evaluation" will be made by Chao Ti Hsiung.

The fourth presentation "The Stability of Measuring Teacher Performance: Implications for Teacher Evaluation" will be made by Zurida Ismail.

Session C-3

RELATIONSHIPS AMONG BIOLOGICAL MISCONCEPTIONS, REASONING ABILITY, MENTAL CAPACITY, VERBAL I.Q., AND COGNITIVE STYLE

Anton E. Lawson
Arizona State University
Tempe, AZ 85287

Lois Thompson
Chaparral High School
Scottsdale, AZ 85251

Students often hold numerous misconceptions about natural phenomena. For them to overcome their misconceptions, they must become aware of the scientific conceptions, the evidence which bears on the validity of their misconceptions and the scientific conceptions, and they must be able to comprehend the logical relationships among the evidence and alternative conceptions. Because formal operational reasoning patterns are necessary to comprehend these logical relationships, it was predicted that, following instruction, formal operational students will hold significantly fewer misconceptions than their concrete operational classmates.

To test this hypothesis, 131 seventh grade students were administered an essay test on principles of evolution and heredity, following instruction on those topics. Responses were categorized in terms of the number of misconceptions present in their responses. Number of student misconceptions was compared to reasoning ability (concrete, transitional, formal), mental capacity (<5, 5-6, 7), verbal I.Q. (low, medium, high), and cognitive style (field dependent, intermediate, field independent). The only student variable consistently and significantly related to the number of misconceptions was reasoning ability. Thus, support for the major hypothesis of the study was obtained.

UNDERSTANDINGS AND MISCONCEPTIONS OF BIOLOGY CONCEPTS HELD BY STUDENTS ATTENDING SMALL HIGH SCHOOLS AND STUDENTS ATTENDING LARGE HIGH SCHOOLS

William D. Simpson
Tipton High School
Tipton, OK 73570

Edmund A. Marek
University of Oklahoma
Norman, OK 73019

Do students from small high schools show fewer understandings and more misconceptions of biology concepts than do students attending large high schools? Fifty students attending large high schools (enrollments exceeding 900 students) and 50 students attending small high schools (enrollments less than 150 students) were randomly selected and then evaluated on their understandings and misunderstandings of four biology concepts: diffusion, homeostasis, food production in plants, and classification of animals and plants. Students attending small high schools showed fewer instances of understanding and more instances of misunderstanding the concepts of diffusion and homeostasis. These differences were due to a higher percentage of students in large schools capable of formal operations; sound understanding of diffusion and homeostasis required students to use formal operations. No difference was observed between the large and small school samples for the concepts of food production in plants and classification of plants and animals. Students in the small school sample lived in agricultural communities and their daily experiences allowed them to develop some understanding of food production in plants and prevented instances of misunderstandings from being developed. Classification of animals and plants required concrete operations to understand; therefore, students in small schools were capable of developing sound understanding as well as were students from large schools.

STUDENT MISCONCEPTIONS OF PHYSICAL SCIENCE CONCEPTS: IMPLICATIONS FOR SCIENCE INSTRUCTION

Paul Eggen
University of North Florida
Jacksonville, FL 32216

Sandra McDonald
St. Johns County School Board
St. Augustine, FL 32084

Don Kauchak
University of Utah
Salt Lake City, UT 84109

A study designed to assess the thinking of junior high school students with respect to density and related concepts was conducted. The study was founded in the research on "alternative frameworks" that has received considerable attention in the recent research literature.

The subjects were 65 ninth graders who had successfully completed a course in physical science as eighth graders and 46 eighth graders who were beginning the identical course. They were directed to use their observations to arrive at a series of conclusions about the concept of density, and were further directed to identify the best choice of reasons for the conclusions.

The results indicated no significant differences between the groups and that all subjects had significant misconceptions about the concept of density. In spite of having taken a physical science course with specific objectives aimed at the concepts on the criterion measure, the ninth graders' thinking was dominated by their experience and intuition rather than by the observations they were supposed to make. They also revealed substantive uncertainty about the concepts of mass and volume, which provide the foundation for the concepts being investigated.

The results have serious implications for science teaching. The study suggests that the traditional science courses students take in the junior high school curriculum are not eliminating the misconceptions they acquire in elementary school. The misconceptions often remain since this is one of the last opportunities they have to study science at a descriptive level.

Session C-4

TEACHING SCIENCE FOR CONCEPTUAL CHANGE IN PRIMARY GRADES: PROBLEMS AND PRACTICES

Primary Teachers' Syntactic, Substantive and Pedagogical Knowledge of Science Lessons

Deborah C. Smith
University of Delaware
Newark, DE 19716

Nine primary grade teachers were clinically interviewed about their views of teaching and learning science, their knowledge of the physics related to light and shadows, and their knowledge of children's thinking in that domain. Teachers' beliefs about teaching and learning science centered around an empiricist position; children learned science through "hands on" activities in which sensory information was used to draw conclusions about events. Few teachers referred to the role of children's own ideas, predictions and explanations. Their own teaching roles were characterized as those of motivator, knowledgeable guide, and refiner of children's ideas.

In their knowledge of light and shadows, teachers revealed misconceptions similar to children's ideas. They thought of light as a static presence which illuminated objects so that we could see them. This view resulted in incorrect predictions about color and vision, shadows, reflection and re-fraction. While some could produce applicable terms such as rays, waves, and refraction, few could use them correctly, consistently or predictively.

Most teachers could accurately predict information which children would not know; none knew what primary children did believe about light and shadows. Most felt that children would already understand that shadows were formed by the blocking of light, for example.

The construction of expertise by teachers, when viewed as a process of conceptual change, can be seen to involve more than just a change in understanding the science content. Teachers' beliefs about teaching and learning science and their knowledge of children's ideas are areas requiring substantial change as well. Implications for preservice and inservice work are discussed.

Primary Teachers' Current Practices and Needed Expertise in Science Lessons

Daniel C. Neale
University of Delaware
Newark, DE 19716

Eight primary teachers who had been recruited for a summer program in science teaching were videotaped teaching science lessons in their own classrooms during the previous spring. A detailed analysis was made of the lessons in order to describe teachers' science teaching practices and to compare these practices with the requirements of a conceptual change teaching model.

Five of the eight teachers followed a familiar pattern of direct, didactic teaching of particular concepts taken from science texts. Interaction patterns were almost entirely a rapid question-answer-evaluation format in which teachers asked low-level factual questions and received only the shortest of answers. Science activities were either absent or brief and tangential to other lesson content. Three teachers taught activity-oriented lessons. The connections between activities and science concepts were uncertain, and children were frequently confused or inattentive.

Comparing the eight lessons to prescriptions from the teaching model, a number of vital features were absent:

1. Lessons were not directed toward eliciting children's conceptions of phenomena nor toward challenging children's conceptions in order to stimulate conceptual development.

2. Rarely did any teacher refer to past or future science content in relation to the lesson being taught.

3. Children had few opportunities to test out their own ideas against first-hand observations or against the ideas of peers.

4. During activity-based lessons, teachers did not have appropriate classroom management rules and routines to prevent confusion and disruptions. Furthermore, the activities were not systematically related to science concepts either through introduction, discussion, or summary.

Primary Teachers' Perceptions of Barriers to Teaching Science

Elizabeth Wier
University of Delaware
Newark, DE 19716

In a typical primary school, science is often a neglected subject. Even if it is taught, it is often through the study of textbooks rather than through activities guided by a knowledgeable teacher. Studies have shown that a number of obstacles impede the teaching of science at the primary level. Nine primary teachers enrolled in a summer science teaching program described many of the obstacles in an initial interview on their science teaching. The barriers they encountered included lack of or inadequate time, equipment, prerequisite skills, and supervisory help.

The greatest barrier appeared to be time. Generally, it was not preparation time that was the problem; rather, the teachers did not have time to teach science because administrators placed a high priority on the teaching of reading and math and a low priority on science. A major reason for this lack of emphasis on science was that it was not included in the standardized test administered statewide, nor were district science objectives tested. Thus, the teachers felt pressured to spend a great deal of time on the "basics" and had little time to teach science. The next greatest barrier was the lack of equipment and of funds to purchase materials for science.

Another obstacle was inadequate prerequisite skills. Many of the teachers indicated a lack of confidence in what to teach, how to teach it, and how to manage the class while teaching science. First, they described a lack of scientific knowledge, indicating that the few science courses they took were not useful in teaching elementary science. Secondly, most reported that their science methods courses, if they had taken any, had not adequately prepared them to teach science. Finally, approximately half of the teachers expressed a lack of confidence in managing the classroom during activity oriented lessons.

An additional barrier, mentioned by more than half of the teachers, was the lack of science supervisory help in their schools or districts. They did not know where to go to get help in teaching science and often reported feeling isolated in their efforts to teach science.

AN ANALYSIS OF FACTORS INFLUENCING THE ADOPTION AND IMPLEMENTATION OF STS THEMES

Janet Carlson Powell
The Colorado College
Colorado Springs, CO 80903

Emmett L. Wright
Kansas State University
Manhattan, KS 66506

This research was designed to determine why science teachers are not adopting and implementing science-technology-society (STS) themes. Kansas middle school science teachers were surveyed to answer four specific questions:

1. What is the relationship between the amount of teacher preparation time and the adoption of STS themes?
2. What is the relationship between the amount of teacher preparation time and the implementation of STS themes?
3. What is the relationship between teacher characteristics and the adoption of STS themes?
4. What is the relationship between teacher characteristics and the implementation of STS themes?

Teacher preparation time is defined as the number of minutes available each week to a teacher to prepare new materials, grade papers, or take care of other classroom related business.

Teacher characteristics for this study are generally defined as the internal and external factors that affect a teacher's curricular decisions. Internal factors are those controlled primarily by the individual teacher, such as background and academic degree. External factors are those which have a direct influence on the teacher but are not under his or her direct control, such as administrative support and age.

Adoption is the acceptance of an idea. It is the action that precedes the process of implementation. Implementation is all the events and activities that a teacher or administration goes through in the first few years of trying something new.

The data collected were analyzed using descriptive statistics, content analysis, and multiple regression. The analysis permitted the following conclusions to be reached:

1. The amount of preparation time available did not seem to influence adoption of STS themes, but was a major factor affecting the implementation of STS themes.
2. Internal teacher characteristics accounted for a small amount of the variance of adoption of STS topics. Those that seemed to matter were: belonging to a professional organization and amount of background knowledge about STS topics.

3. Internal teacher characteristics accounted for a larger portion of the variance of implementation of STS themes. Specifically, background knowledge and experience were the characteristics identified.

4. The external factor primarily affecting adoption of STS themes was administrative support for the concept of science-technology-society.

5. The major external factor affecting the implementation of STS themes seemed to be resources, either that they do not exist or that they are not reaching the teachers.

AN ANALYSIS OF FOUR METHODS WHICH ASSESS STUDENTS' BELIEFS ABOUT SCIENCE

Glen S. Aikenhead
University of Saskatchewan
Saskatoon, Canada S7N 0W0

The study investigated the degree of ambiguity harboured by four different response modes used to monitor student beliefs about science-technology-society topics: Likert-type, written paragraph, semi-structured interview, and empirically developed multiple choice. The study also explored the sources of those beliefs. Grade 12 students in a Canadian urban setting responded, in each of the four modes, to statements from Views on Science-Technology-Society.

It was discovered that TV had far more influence on what students believed about science and its social, technological context than did numerous science courses. The challenge to science educators is to use the media effectively in combating naive views about science.

Regarding ambiguity in student assessment, the Likert-type responses were the most inaccurate, offering only a guess at student beliefs. Such guess work calls into question the use of Likert-type standardized tests which claim to assess student views about science. Student paragraph responses contained significant ambiguities in about 50% of the cases. The empirically developed multiple choices, however, reduced the ambiguity to the 20% level. Predictably, the semi-structured interview was the least ambiguous of all four response modes, but it required the most time to administer. These findings encourage researchers to develop instruments grounded in the empirical data of student viewpoints, rather than relying on instruments structured by the philosophical stances of science educators.

AN EXPERIMENTAL STUDY OF THE RELATIONSHIP BETWEEN KNOWLEDGE ABOUT NUCLEAR SCIENCE AND ATTITUDES TOWARD NUCLEAR POWER PLANTS

Dennis E. Showers
State University of New York at Geneseo
Geneseo, NY 14454

This investigation assessed the relationship between knowledge about and attitudes toward nuclear energy. Crater stated that positive attitudes toward nuclear energy depend on knowledge about nuclear energy, conflicting with other attitude research. Fishbein and Ajzen's Theory of Reasoned Action, Gagne's instructional model, and Hovland's learning theory approach, provided theoretical background for this study.

The study's purpose was accomplished by attempting to manipulate knowledge about and attitude toward nuclear energy independently. Over 2000 high school students participated in the study. A non-equivalent control group quasi-experimental design was used involving random assignment by intact groups to treatments. A knowledge treatment was designed to increase student knowledge without affecting attitudes. An attitude treatment was designed to change attitudes without changing knowledge, and a control treatment was employed for comparison to the experimental treatments. Each treatment consisted of a videotape with a viewing guide and a homework assignment. The Nuclear Energy Assessment Battery was used as a pretest, posttest, and retention test. Pearson Product-Moment correlation coefficients were applied to pretest scores while the analysis of variance with repeated measures was used to analyze pretest, posttest, and retention test knowledge and attitude scores. The analysis of variance followed by PSI HAT comparisons were used to determine the direction of differences identified by the analyses of variance. A 2x3 analysis of variance was used to assess gender differences on posttest knowledge and attitude scores.

The PPM correlations between knowledge and attitude scores ranged from .31 to .37. The treatments were determined to create significant differences in their respective posttest scores. These effects were not observed in comparing the treatment groups to the control group three weeks later. Males scored significantly higher in knowledge and positive attitudes, but no interaction between gender and treatment was found.

The study concluded that (1) there is a correlation between nuclear knowledge and attitudes, (2) knowledge about nuclear energy can be changed without affecting attitude and attitude can be changed without affecting knowledge, and (3) students show differences in knowledge and attitude based on gender.

DEVELOPMENT OF A LIKERT-TYPE ATTITUDE SCALE FOR PRESERVICE ELEMENTARY TEACHERS TOWARD THE TEACHING OF WATER EDUCATION

Peter M. Mecca
Pennsylvania State University
University Park, PA 16802

Water Education is a concern expressed by many individuals at various levels of society. The concerns range from issues at the local level (e.g., giardiasis in communities in northeastern Pennsylvania) to issues at the state, national, and international levels (e.g., acid deposition in northeastern United States and Canada). Because concerns about the nature of water education have been expressed by members of society, many agencies (e.g., Pennsylvania Department of Environmental Resources, Pennsylvania Department of Education) and individuals (e.g., science teachers, social studies educators) suggested that instruction be provided to students on how science, technology, and society influence one another.

Also, Pennsylvania's Environmental Education Curriculum mandates the teaching of issues related to water education. Support for this position comes from a number of sources, including the Project Synthesis report which states, "Shortages of natural resources formerly taken for granted (energy, water, minerals, land and space) require citizens to view technological developments in new ways." In addition, the National Science Teachers Association recommended that a science curriculum include instruction dealing with knowledge, attitudes, appreciation, and process skills of science related to societal issues. Therefore, the school has been given the responsibility of integrating these mandates into its curriculum.

The purpose of this study was to develop a Likert-type instrument that measures the attitudes of preservice elementary teachers toward the teaching of water education. Following the assemblage of 62 trial statements, the statements were analyzed by a jury of three educators using Edwards' criteria. Statements were either retained, or edited, or rewritten using Edwards' criteria and jury feedback. The 62 statements were then piloted using a sample of preservice elementary teachers (N=74). Data collected from respondents were analyzed using the Likert Attitude Scale Analysis Main Program (LIKRT). Coefficient alpha for the 62 statements was reported at 0.962. Twenty-two statements were selected from the original 62 statements based upon adjusted inter-item correlation and neutral data. These 22 statements were submitted to LIKRT analysis. The results of the study include a 22 item Water Education Instruction Likert Attitude Scale with a coefficient alpha of 0.958.

Session C-6

THE PARTICLE NATURE OF MATTER APPROACH: ITS EFFECTIVENESS ON CHEMISTRY ACHIEVEMENT

Dorothy L. Gabel
K. V. Samuel
Indiana University
Bloomington, IN 47405

Clifford Schrader
Dover High School
Dover, OH 44622

Many high school students find chemistry problem solving difficult. The literature on problem solving in chemistry indicates that problem redescription may be an effective way of improving students' problem solving behavior and consequently chemistry achievement. In order to redescribe chemistry problems, it would appear that students would need to understand the particle model of matter. The purpose of this research was twofold. First, an attempt was made to determine students' entry knowledge of the particulate nature of matter. Second, the effectiveness of emphasizing the particle nature of matter on chemistry achievement was examined.

Sixteen experienced high school chemistry teachers administered the Nature of Matter Inventory to their classes at the beginning of the school year. A random sample of 320 inventories (20 per school) were coded according to seven attributes: conservation of atoms, proximity of atoms to one another, orderliness of particle arrangements, location of particles in the container, constancy of size and shape, particle discreteness, and correct chemical composition. Data indicate that less than 5% of the students have a thorough knowledge of the particle nature of matter before taking the chemistry course.

To determine the influence of instruction emphasizing the particulate nature of matter, teachers were randomly assigned to the treatment and control groups. Students' achievement from five of the control teachers were compared with those of five of the treatment teachers using an analysis of variance nested design. The treatment consisted of emphasizing the particulate nature of matter whenever possible during instruction and having students complete 10 worksheets for 10 different chemistry concepts on which they were required to draw circles representing atoms.

Results indicated that students in the treatment group performed statistically better (0.03 level) than students in the control group on the Particulate Nature of Matter Objective Test, but there was no significant difference on the ACS-NSTA Chemistry Examination. However, the scores on the Particulate Nature of Matter Objective Test indicate that students in both groups have an inadequate knowledge of the particle nature of matter. Consequently, this may be a barrier to chemical problem solving and the understanding of many chemical concepts.

COGNITIVE DEVELOPMENT AND PROBLEM-SOLVING OF AFRO-AMERICAN STUDENTS IN CHEMISTRY

Bonita Alick
Clark College
Atlanta, GA 30314

Mary M. Atwater
Atlanta University
Atlanta, GA 30314

The aim of this study was to investigate the level of cognitive development of Afro-American students enrolled in general chemistry courses at the college level and to determine the strategies used by both successful and unsuccessful students in solving specific types of stoichiometric problems. The question of whether concrete or formal thought is related to successful or non-successful solution of these type problems was addressed.

It was found that no correlation exists between cognitive development and problem-solving strategies. The choice of a strategy is independent of the cognitive development level of the student. The success of the student, in finding a solution to a given task, was found to be dependent on the choice of strategy in some instances and not in others. When solving mole concept problems, with the exception of mole-volume problems, success was not related to the choice of strategy. However, when balancing both simple and complex chemical equations, a systematic strategy proved the student to be successful.

In some instances, cognitive development was found to be significant in the students' odds of success. A student who is formal operational was more likely to be successful when solving mole-volume problems and a complex mole-mole problem than was his concrete operational counterpart. A higher level of cognitive development, which incorporates reasoning, is a crucial factor in solving the more sophisticated types of problems in stoichiometry.

Thus, it was concluded that cognitive development, the choice of a strategy and success are interrelated. The findings of this study may provide insight into effective instructional strategies professors might wish to use by analyzing successful and unsuccessful student approaches to solving specific types of chemistry problems. It may be useful to pattern problem-solving instruction after the methods by which successful problem-solvers find solutions.

THE EFFECTS OF AN EXPLICIT PROBLEM SOLVING STUDY IN GENERAL CHEMISTRY

Diane M. Bunce
The Catholic University of America
Washington, DC 20064

The findings of both information processing psychology and metacognition are recognized by many researchers as necessary for a study of learning. This study looks at the effects of an explicit method of problem solving in college chemistry that incorporates information processing findings and metacognition. Students enrolled in a first-year general chemistry course for health sciences were shown an explicit method of problem solving for stoichiometry problems. Only half the class was specifically instructed to use the method on a take-home quiz immediately following instruction. Students from both groups who did use the explicit method of problem solving scored significantly better on stoichiometry problems in testing situations when such problems were not expected. There was no significant difference between those who used the explicit method and those who did not on stoichiometry problems in testing situations where such problems were expected. Students in the group that was specifically instructed to use the method immediately following instruction used it in higher percentages than did students in the group that was not so instructed.

Poster Session C-7

THE DEVELOPMENT AND VALIDATION OF SCIENCE INSERVICE MATERIALS FOR K-6 TEACHERS

Charles R. Barman,
Indiana University
Indianapolis, IN 46223

In this project, a set of K-6 inservice materials, titled LEARNING ABOUT THINKING AND THINKING ABOUT LEARNING, was developed and field-tested. The purpose of these materials is to provide K-6 teachers with a rationale for teaching activity-based science and to present them with a strategy that will assist them in integrating an activity approach into their existing science materials.

The materials were developed during the first semester of the 1985-86 academic year. The first draft of the materials was field-tested during the beginning of the 1985-86 spring semester. Fifty-five K-6 teachers (group I) were selected for the first field-test effort. The group I teachers were not randomly selected. They were chosen from a group of teachers who volunteered to participate in the project. An attempt was made to select at least two teachers from each K-6 grade level. Group I was asked to complete an evaluation questionnaire to assess the overall effectiveness of the inservice materials.

Appropriate modifications were made in the first draft materials after the first field-test. The revised materials were field-tested toward the end of the 1985-86 spring semester. Fifty-eight K-6 teachers (group II) were selected to participate in the second field-test effort. These teachers were drawn from a different sample than group I. A similiar procedure to the one used to select group I was employed to select group II. Group II was also asked to complete the same evaluation questionnaire that was used with group I.

The frequency of responses to the evaluation questionnaire indicated that groups I and II agreed that the main goals of the inservice materials had been accomplisherd. A Chi square test was also used to compare the evaluation responses of both groups. The results of these tests indicated that the intensity of group I's agreement was stronger than group II's.

COGNITIVE CONFLICT AND SCIENCE CONCEPTIONS

Garth D. Benson
The University of Calgary
Calgary, Alberta T2N 1N4 Canada

This research, which is on-going, investigates the development of an alternative epistemological framework in intending elementary science teachers through the use of cognitive conflict. The study is founded on the research literature in the philosophy and sociology of science as well as the "constructivist perspective" of knowledge.

The subjects were 112 education majors enrolled in an elementary science methods class. They were instructed to prepare a 10-minute microteaching lesson that illustrated one of the scientific processes and scientific content that was consistent with the elementary science curriculum. The lessons were videotaped and analyzed, in class, for the consequences that the presentation had for the status of scientific knowledge. In addition, each student recorded, on audio cassettes, one lesson presented during the practice teaching round. The lessons were transcribed and analyzed according to the guidelines established for the microteaching assignment.

The data suggest that intending elementary teachers are unaware of the possiblity of viewing scientific knowledge from an alternative perspective and that a constructivist framework is unfamiliar to them. Individuals involved in the study indicate that cognitive conflict occurs and thus this suggests that teaching for alternative epistemological frameworks is a possibility.

The results suggest several important implications for science teaching. If the development of cognitive conflict has long-term effects on individuals' epistemological perspectives, do they teach science solely from the new perspective? Does the change in perspective influence the intending teachers conception of science? Does the development of cognitive conflict influence the status of scientific knowledge that is provided during classroom lessons?

OBSERVATIONAL ANALYSIS OF THE EFFECTS OF EQUALS TRAINING ON PARTICIPATING TEACHERS

Catherine R. Conwell
Richard B. White
University of North Carolina at Charlotte
Charlotte, NC 28223

The EQUALS program provides an innovative approach for solving the problem of the underepresentation of females and minorities in mathematics and science courses and careers. One component of the

EQUALS program is the inservice training program for K-12 science and mathematics teachers, counselors, and administrators. The training provides instructional strategies to encourage cooperative learning; curriculum materials to promote problem solving and skills in spatial visualization; and classroom activities that emphasize a hands-on approach to understanding math and science concepts. To date, the EQUALS inservice training has been implemented in the Charlotte-Mecklenburg Schools during the school year 1984-85 and again in 1985-86. During the 1985-86 academic year, 42 teachers representing grade levels from kindergarten through 12th grade participated in a qualitative study that described the impact of the 30 hour inservice experience. Teacher testimony included descriptions of changes in four teaching practices. The purpose of this study is to determine whether those results are corroborated with observational data and if so, to describe the degree to which the practices were changed.

A Multiple Time Series design will be employed. The design entails repeated measures prior to the intervention of the EQUALS inservice and after intervention for an experimental and equivalent control group. Six EQUALS-trained teachers representing grades 4-6 in three different schools comprise the experimental subjects and a control group composed of six teachers from three schools similar to the EQUALS participants will also be observed. A time sampling system will be used. Teachers will be observed for 20 seconds and then the observers will spend the next 10 seconds indicating whether the teacher was implementing problem-solving, cooperative learning, learning stations and/or career education.

The observation schedule will be completed in May, 1987. At that time, the results will be collected and analyzed. Finally, the results of this quantitative study will be compared to the results of the previous qualitative study.

EFFECT OF FIELD ACTIVITIES ON STUDENT AFFECTIVE RESPONSES AND COGNITIVE PERFORMANCE

Ernest L. Kern
Southeast Missouri State University
Cape Girardeau, MO 63701

A low motivational climate is characteristic of many introductory, general education science courses at the university level. It has been well established that student motivation in a learning experience is, in large part, influenced by the affective responses of the students to that experience.

To determine the effect of field activities on the affective responses of students in this study, very different approaches were used by the same instructor in teaching two sections of Earth Science Laboratory.

One section was conducted in the traditional manner: primarily classroom activities utilizing a laboratory manual. A field-oriented, on-site approach was employed for the second section. Content topics were virtually identical in the two sections.

Pre-test data on both classes for values (sense of importance), attitudes (sense of enjoyment), and interests as related to the 30 major topics or themes of the course indicated no significant differences between the 2 classes. At the end of the term, post-tests on the same set of items revealed highly significant differences between the two groups. Students under the field-oriented approach left the course feeling much higher levels of importance, interest, and enjoyment associated with the learning experience than did students in the traditional lab.

Cognitive gains were also evaluated using achievement on the final examination as the primary indicator. On the set of exam items testing knowledge learning (the simple remembering of information), both classes exhibited almost identical performances. However, on the series of items requiring more advanced mental operations, the field-oriented class scored significantly higher, suggesting the possibility of enhanced higher-order learning.

Results further suggest that the affective character of students regarding the experience may have important implications on course and departmental enrollments. Students in the field lab were much more willing to recommend the course to other students, and they also displayed a greater interest in taking additional courses in the earth sciences.

INFORMATION THEORETIC ANALYSIS OF SCIENCE LEARNING BY COLLEGE BIOLOGICAL SCIENCE STUDENTS

David W. Kopp
Gene W. Moser
University of Pittsburgh
Pittsburgh, PA 15260

The purpose of this investigation was to examine the informational structure and quality of prose cognition sequences evoked by college biology students after they read a passage on vaccination. Students were required to complete an immediate prose recall. One month later the students completed a prose recall and a science concepts objective test. Other trait variables included a college entrance test on verbal ability, and the student's gender.

The immediate and delayed recalls were analyzed for sequence structures consisting of: (1) science words, (2) nouns, (3) total words, (4) the nouns used in both the recalls and found in the learning task passage. Thirty information theoretic variables were calculated from the sequence structures of both the immediate and delayed recalls - representing the linguistic structure utilized by the students in organizing the recall of concepts remembered from the reading task.

A discriminant analysis of test performance, verbal ability, or gender was performed. The information processed in the four verbal structures of the immediate and delayed recalls was found to significantly discriminate for the gender of students; performance on the delayed objective test; high and low performance on the New Purdue Placement Test in English; and for combinations of these variables. *A posteriori* correct classification of students (based upon the canonical of information variates) as to their gender and/or performance was at a level higher than that due to random or chance assignment in all analyses performed.

The principal discriminators were information processed in words evoked independent of other words in the sequence - H(X), H(Y), and H(X,Y) of the immediate recall. Secondary discriminators were found to be chunking information (LTM) and information encoded for long term memory in a Markov process.

The results of this investigation validate the use of information theoretic variables to quantify the linguistic structure of cognitions of students for the concepts presented in science text material. The structure of the recalls represented by the information variables could significantly discriminate performance on the objective test, an independent measure of the transformation and integration of information into memory structures.

Further analysis of the students correctly and incorrectly classified according to the discriminant functions of the sequence structure of recall may provide a basis for diagnostic measures for evaluating student performance in classes utilizing textual material and objective test performance. These results and suggestions for further investigation provide important implications for the teaching of science.

AN EXAMINATION OF MULTIPLE CHOICE ITEMS USED TO MEASURE THE SKILL OF VARIABLE IDENTIFICATION

Danny L. McKenzie
Christine Kuehn
Catherine Kennedy
University of South Carolina
Columbia, SC 29208

Edward L. Shaw, Jr.
Southeastern Louisiana University
Hammond, LA 70402

The increased emphasis on accountability in public education has resulted in numerous state and local testing programs. Several states (e.g., Florida, South Carolina, Texas) have recently included a science component in the assessment of elementary and middle school students. This science component often includes items designed to measure process skill ability. Typically, process skill items are multiple choice format and do not include interaction with materials other than pencil and paper.

Testing strategies employed by classroom teachers or district level personnel to measure process skill ability may take various forms. For example, in assessing students' ability to identify variables in an experiment, a teacher may use a checklist during a hands-on investigation. This approach would involve asking each student to identify appropriate variables in the experiment. Another logical method of assessment would be to use pencil and paper items in which an experiment is described and the student asked to identify appropriate variables. However, students may also be required to identify variables from a written hypothesis, a science question involving variables, or from a description of the results of an experiment. While all these question formats may be employed, it is questionable if they all function similarly.

The purpose of this pilot study is to examine the performance of middle school students on four types of multiple choice items used to assess the students' ability to identify manipulated and responding variables. The items will differ only in the stimulus material presented to the student. Stimulus material will be either a question focusing on the relationship between two variables, a hypothesis, a description of an experiment, or a description of the results of an experiment.

In addition, student performance on these item types will be compared to performance on a standard Piagetian Interview Task of variable identification.

The following research questions will be addressed in the study and will be discussed at the poster session.

1. Is there a difference in student performance across the four item types?

2. Is there a difference in the students' ability to identify manipulated variables and responding variables?

3. Is there a difference in the correlations between the results of the Piagetian interview tasks and the four item types?

THE ROLES OF VERBAL OPINION AND CHESS PLAYING BEHAVIOR INFORMATION IN HIGH SCHOOL BIOLOGY COURSE PERFORMANCE

Gene W. Moser
University of Pittsburgh
Pittsburgh, PA 15260

The behaviors of 83 high school biology students in tournament chess games and 15 minute written opinions about the nuclear winter issue were quantified for the information processed in these tasks. The chess tournament was for the duration of the school year. All of the students were taught by one biology teacher, who was not informed of the investigation objectives. Chess game outcomes were used to segregate information data, as to winners and losers. It was found that different patterns of linear relationships occurred for information variables, on the basis of game outcomes.

The information flow of chess game piece moves and that for a sequence of 42 key words used in written opinions was significantly related to the number of course points used for determining final biology course grades. However, a greater linear relationship was found for problem-solving behaviors and course achievement than for the sequence of key words used in writing an opinion on the issue of the nuclear winter threat. There were larger coefficients of correlation between chess playing and verbal opinion information variables than found with the total points earned by students enrolled in the high school biology course.

The findings confirm earlier studies in which the quality of different kinds of behavior can be quantified with an information theoretic model. That model is sensitive to information flow found in sequences of evoked behavior, as to the context of tasks and the modality of evocations.

INTRODUCTORY RESEARCH EFFORTS ON MICROCOMPUTER-BASED LABORATORIES

John C. Park
North Carolina State University
Raleigh, NC 27695

There has been much research on the outcomes of the use of computer software on learning. Most of the reported research indicates that use of computer software has a positive effect on both learning and attitudes. Meta-analysis of the research on the effects of computer-based teaching reveals that the computer can be used to help learners become better readers, calculators, writers, and problem solvers. However, research in the influence of the microcomputer on scientific problem solving is not extensive and more research is needed. Since the development of scientific problem solving skills is one of the goals for science education, science teachers should consider devoting more time to the use of the microcomputer as a learning tool.

An emerging use of the microcomputer in the science classroom is to monitor experiments and gather data. Robert Tinker (Technology Education Research Center, Cambridge, MA) refers to this use as "Microcomputer-Based Laboratories," or MBL. A few characteristics which make MBL attractive to the science teacher include the immediate collection, storing, and transformation of experimental data while science experiments proceed. This allows for a reduction in labor from the student viewpoint.

Research in this new technology is in its infancy. Initial research efforts (John Layman, University of Maryland) have operated on assumptions that the reduction in mundane paperwork allows students to focus on the concepts involved in the experiment. Since there is less time spent in data gathering, more time can be and will be spent on interpreting and evaluating data, and replicating experiments. It is assumed that MBL enables and motivates the students to practice the process of scientific problem solving. This assumption needs to be tested.

This poster session will report on the development of MBL apparatus, the teacher training programs, and the research questions and designs we will be implementing over the next three years. We will share research data of an initial pilot study on student interaction with the developed MBL apparatus.

INNOVATION IN SCIENCE EDUCATION - THE EXPERIENCE OF INCORPORATING SENIOR HIGH SCHOOL STUDENTS INTO THE RESEARCH COMMUNITY

Naama Sabar
Vered Gingburg
Tel Aviv University
Ramat Aviv 69978, Tel Aviv, Israel

In a new suburban high school, a group of highly motivated and devoted school teachers decided to implement a series of innovations in education, among them is the "research class" which is described below. As part of a new policy of the Ministry of Education schools were encouraged to exercise greater autonomy. Even with the previously known very rigid matriculation examinations some flexibility was shown toward the school's curriculum initiatives which the students could undertake instead of a conventional subject. Within this framework of school-based curriculum developments, our school offered its 11th grade advanced students in science a program that combined biology studies with an actual research project in a research institute to be part of their matriculation requirement. Eighteen students were chosen. This group had biology classes at school and worked one day a week during school year in addition to weekends and vacations as needed. The project lasted 18 months, within which the students had to hand in the written research report guided by a scientist from the research institute.

The majority of students who stayed were enthusiastic about the opportunity to experience the usage of a literature data base, learn research techniques, encounter real research difficulties and the challenge to be trained in reporting about their work. The assigned scientists were just as pleased with their students, praising their intellectual ability, their commitment and responsibility.

We have carried a non-participant observation in most of the classroom lessons and some of the work at the institute, which exposed difficulties, mainly in respect to the classroom teaching.

The teacher believed in teaching principles and applications instead of facts and details. Apparently this strategy was suitable only for a small group of these advanced students.

Differences were also observed between boys' and girls' mode of participation.

INITIAL DEVELOPMENT OF AN ENVIRONMENT FOR STUDENT AUTHORSHIP OF GEOLOGICAL REASONING SYSTEMS

Charles R. Ault, Jr.
Lewis and Clark College
Portland, OR 97219

Stan C. Kwasny
Erich Smythe
Indiana University
Bloomington, IN 47405

Roger F. Boneham
Indiana University
Kokomo, IN 46902

Thomas E. Kesler
Purdue University
West Lafayette, IN 47907

Structural Geology students were studied as they explored for oil in a simulated geologic world. From these efforts, several expert systems have been developed which are providing insights into how geological reasoning, in three dimensions, leads to the discovery of geological structures and how those structures are related to the task of finding oil. The goal of fully automating the transfer of expertise from student "expert" to rule-based system is unattainable at present, but steps have been taken toward that goal. The philosophy, motivation, and initial achievements of this task are discussed.

BELIEFS AND PROBLEM SOLVING IN GENERAL CHEMISTRY: A QUALITATIVE STUDY

Carolyn Sue Carter
George M. Bodner
Purdue University
West Lafayette, IN 47907

Recent work in mathematics education has shown that mathematical beliefs influence: (1) strategy selection, (2) access to potentially useful information, (3) approach to the problem, (4) length of time spent working on a problem, (5) the decision about when a problem is solved, and (6) what counts as a math problem. Belief systems serve to "establish the context within which resources, heuristics and control operate."

In mathematics, some beliefs have achieved widespread acceptance, leading to phenomena such as math anxiety and math avoidance. A similar problem exists in science. Belief systems make up the individual's world view and exert a powerful influence on the way a student approaches a task. Many students are successful in solving classroom physics or chemistry problems, which they can do by applying their stock of equations, but show little concern for the science behind the equations. For them, science is equations. Thus, when faced with a conceptual question, or a problem where an equation is not immediately applicable, the student has no conceptual background to rely on, and furthermore, sees no reason to have developed such a conceptual understanding.

This study examines how first-semester general chemistry students go about solving both exercises and non-routine problems in order to investigate the role of context or beliefs in determining how students learn chemistry and solve chemistry problems.

COMPUTER FACILITATED CONCEPT MAPPING: A TWO YEAR STUDY INVOLVING 1000 HIGH SCHOOL CHEMISTRY STUDENTS AND THEIR INSTRUCTORS

Laine Gurley-Dilger
Township High School District #214
Rolling Meadows, IL 60008

Educational research has established that concept mapping (CM) is a note-taking technique that facilitates "meaningful" learning. It would appear that teachers are reluctant to commit class time to the teaching and evaluation of CM at the expense of time previously allocated to course content areas. The only solution to this dilemma comes about if we can become so efficient at teaching and evaluating CM that in-class time used for this purpose is minimized.

Therefore, Township High School District 214 and Northern Illinois University jointly proposed a study in December, 1984 with the following goals:

> It is the goal of this study to instruct 6-10 chemistry teachers and 500 students enrolled in junior chemistry in how to concept map chemistry assignments using only one day of in-class time and computer aided instruction, CAI. An interactive computer tutorial and audiovisual aids have been created for this purpose.
>
> A second and equally important goal of this study is to demonstrate that microcomputers can be used by faculty and students to create concept maps. Students and teachers will realize that computer-generated concept mapping allows uniformity, flexibility, and storage which are impossible to achieve by paper and pencil methods.
>
> A third and final goal of this study is to investigate student achievement in chemistry by comparing the achievement of the students using concept mapping to those students using traditional note-taking methodologies. All students in both the experimental and control groups are enrolled in Chemistry in Township High School District 214 and use the 1981 edition of Cebco Chemistry.

A COMPARISON OF THE INSTRUCTIONAL EFFECTIVENESS OF DIRECTED DISCOVERY AND VERIFICATION LABORATORY ACTIVITIES

Jerry Ivins
Northwest School District
Cincinnati, OH 45239

Glenn Markle
University of Cincinnati
Cincinnati, OH 45221

Two questions are addressed by this study: (1) Do students who are introduced to science concepts through textbook laboratory exercises followed by textbook readings and classroom discussions learn those concepts better than do students who have the concepts introduced through textbook readings and classroom discussions followed by verification labs? (2) Do students who are introduced to science concepts through textbook laboratory exercises followed by textbook readings and classroom discussions retain those concepts better than students who have the concepts introduced through textbook readings or classroom discussions followed by verification laboratory activities?

A review of the literature revealed considerable historical support for using laboratory activities to introduce new science concepts. This support was based upon the personal preference and logic of the writers. In spite of earlier support for laboratory-based science instruction, the literature review revealed that this approach is not as widely used as in the past. Decisions to reduce the time and resources committed to laboratory instruction have been based upon the belief that laboratory activities do not contribute to learning science content. Recently, Renner and others reported that a sequence of instruction in which laboratory activities were used to introduce concepts increased achievement and improved students' attitudes toward science. However, this research-based evidence used a procedure that involved major revisions of the curriculum, making implementation difficult for most teachers. This study attempted to determine if typical textbook laboratory exercises (usually verification labs) could improve achievement and retention if they were used to introduce new concepts (i.e., used as directed-discovery laboratory exercises).

The theoretical base for this study was information processing theory which suggests that first-hand laboratory activities may help students develop better related cognitive structures by establishing sharper mental images for students. These "structures" should provide better routes to long-term memory. The implication is that existing textbook laboratory activities when used as directed-discovery learning labs to introduce new concepts should result in greater achievement and retention than verification labs.

The sample consists of seventh grade earth science students enrolled in homogeneously grouped classes in a suburban junior high school. The families in the attendance area of the school are predominately white and middle class.

The dependent variables are scores from an achievement test administered on two different occasions: shortly after the instruction and again approximately four weeks later. Two scores are determined. The first is a measure of mastery of the science content addressed by both the laboratory activities and the textbook readings and classroom discussions (laboratory relevant information); the second score is a measure of mastery of information included in the textbook and classroom discussion but not in the laboratory exercises (laboratory incidental information). Achievement test scores are statistically adjusted to account for the student's academic ability and pre-instructional knowledge of the content.

The findings will be considered in terms of the Information Processing Theory and recommendations for classroom teachers will be discussed.

ENVIRONMENTAL ETHICS DEVELOPMENT OF ELEMENTARY SCIENCE STUDENTS

Doris A. Simonis
University of Montana
Missoula, MT 59812

Most theorists and researchers on children's thinking and learning have focused on social development and on making choices for "good" that is personal, familial, or social. The shift in concern from selfish survival needs to responsibility and concern for others is typical as people mature. However, Gilligan suggests, the transition may have a "feminine" rather than a "masculine" focus. Some people seek truth in higher levels of connectedness and in caring human relationships, while others tend to value more autonomous generosity and strive for a hierarchical excellence.

In environmental education, "connectedness" is inherent in concepts like food webs and matter-energy relationships. It is also an encompassing perspective on planet Earth, our home, that gives importance to rocks, water, air, soil, and other non-living elements that cycle throughout the ecosphere. There seems to be a "feminine" orientation in the valuing of interactions with nature and in concern for the natural environment as a system of interrelationships between diverse species and their habitats. My questions are:

1. Would the development of environmental ethics parallel stages of rational and ethical development outlined by Piaget and Kohlberg, respectively, or would they be less linear?
2. Would girls be more likely than boys to cling to animistic ideas (see abiotic elements as "alive") as they advance in school?
3. Does animistic thinking contribute to respect for the environment?

MENTAL REPRESENTATION OF TEXTBOOK GENETICS PROBLEMS: STUDENTS, FACULTY, PHYSICIANS, AND GENETIC COUNSELORS

Mike U. Smith
Mercer University School of Medicine
Macon, GA 31207

Problem-solving theorists today generally accept the thesis that novices categorize problems according to the "surface structures" while experts sort according to "deep structure"--the underlying content-specific principles applicable to the problem. In a recent study of computer programming problems, researchers observed essentially the same dichotomy between the categorizations of undergraduate and graduate students but the four programming managers subjects sorted the problems according to the "kind of programmer to whom they would give each problem." This finding suggests two important questions: (1) Does the deep structure/surface structure distinction accurately characterize the difference between the mental representations of experts and novices or only the difference between novice students and expert teachers? (2) Is the mental representation of problems (as evidenced by problem sorting) more influenced by the way these problems are regularly encountered and addressed?

The purposes of this study, therefore, were as follows:

1. to attempt to corroborate the surface/deep structure distinction between the mental representations of students and faculty menbers,
2. to identify the differences among the mental representations used by a broader group of subjects, including two groups of professionals,
3. to extend the research into another content area,
4. to examine more closely the nature of the categorization procedure and how it is applied,
5. to reexamine the similarity of keywords identified by the various subjects, and;
6. to reexamine the collected data so as to compare successful and unsuccessful problem solvers.

Subjects representing a broad range of genetics problem-solving expertise were presented a group of 24 typical genetics problems and asked to organize the problems according to how they would solve them. Subsequently, they solved a group of three classical genetics problems to serve as a basis for grouping the subjects into successful and unsuccessful groups. Six subjects were presented these tasks during individual interviews.

Although no conclusions can be drawn until the data collection and analysis is complete, preliminary analysis supports the proposition that the organizations used by unsuccessful students depend on the surface characteristics of problems, while teachers use more content-specific deep structure characteristics. Professionals such as practicing physicians and counselors, however, tend to group problems according to the manner in which they are typically encountered and addressed, e.g., human vs. nonhuman. The implications of this and other findings to classroom instruction and problem-solving theory will be discussed.

DIFFERENCES IN SCIENCE TEACHING ATTITUDES AMONG UNDERGRADUATE AND GRADUATE SCIENCE EDUCATION MAJORS

Victor L. Willson
Robert K. James
Texas A & M University
College Station, TX 77843

This study complements, partially replicates, and extends a study by Willson and Horn on differences among various science educators. Specifically, this study compares the attitude toward teaching science of junior, senior, post-BA teaching certification, and MA students. Attitudes are examined on two dimensions: pedagogy and student orientation.

In research performed by Post et al and Willson and Horn, the focus was on developing theoretical models which would explain observed differences in the attitudes toward teaching mathematics (Post et al) and science (Willson and Horn). The studies concluded that the philosophical and experiential approaches to teaching of various educational groups are determined by their situations. That is, principals and science teachers in secondary schools follow behavioral models in their attitudes toward teaching, while college teacher trainers follow cognitive models. Student teachers exhibit attitudes which are somewhat similar to, and yet different from, both their college trainers and their public school teacher colleagues. How and when student teachers change in attitudes toward teaching science is important to the science education discipline, for the impact that researchers and curriculum developers have on secondary science is determined in large part by these attitudes.

Willson and Horn postulated three possible models for attitude formation and change in undergraduate science education students. The three models are compared in this paper with responses of juniors, seniors, BA-certification students, and beginning MA students with no teaching experience. The three models predict different patterns for means and variances for the groups.

MIDDLE SCHOOL TEACHER CERTIFICATION: FACT OR FANTASY?

Edward L. Shaw, Jr.
Bryan L. Schisler
Southeastern Louisiana University
Hammond, LA 70402

The National Science Teachers Association gave credence to middle/junior high schools by creating a separate division in 1975. By 1980 science teaching in the middle school was being evaluated and the results were alarming. These results indicated a decline in students' interest in science. In the past six years what has been the reaction to these problems as reflected in middle school teacher certification requirements?

The purpose of this project was two-fold: to provide data concerning the current status of middle school teacher certification nationwide and to determine the emphasis being placed on science and math middle school certification requirements.

Data were collected using an 11-item questionnaire. The questionnaire was mailed to all 50 states. The questionnaire asked questions concerning the current status of middle school certification in that state. Data from the questionnaire were received from all states and were compiled.

The findings of this study show:

1. Twenty-four states require certification for middle school/junior high school teachers.
2. Sixteen of the 24 states requiring certification assign specific subject area certification in math and science.
3. A great variety exists in the grade levels designated as middle/junior high schools.
4. Twenty-two of the 24 states requiring middle school/junior high school certification have programs which provide for add-on certification to either the elementary or secondary certificate.
5. Twenty-four of the respondents favored the middle school/junior high school certification concept, 15 opposed the idea, and 11 expressed no opinion.

Problems exist in the certification of middle school teachers. States are interested in having middle school teacher certification but this places restrictions on hiring and assigning qualified teachers. Although science and math are being taught in middle schools, a clear majority of middle school science and math teachers is not being mandated to meet specific subject area requirements.

AN ANALYSIS OF THE EFFECTS OF USING INSTRUCTIONAL GAMES TO TEACH SCIENCE TO ELEMENTARY SCHOOL STUDENTS

Edward L. Shaw, Jr.
Southeastern Louisiana University
Hammond, LA 70402

Kevin C. Wise
Southern Illinois University
Carbondale, IL 62901

Although there are a variety of games available from both commercial and non-commercial sources that are compatible with science instructional objectives, many teachers don't use games. Even in elementary schools, where teachers might be more receptive to the notion of a game as a form of instruction, science lessons are seldom presented in the game mode. Possible reasons for the relatively rare use of instructional games might include a simple lack of awareness on the part of teachers about games, or a diversion of attention to currently more popular teaching tools such as microcomputers. Importantly, teachers may simply not consider student involvement in games as real instruction. Little research is available about the effects of using games in science instruction that could be used by teachers in deciding if or how games might be applicable in their own instructional contexts.

The purpose of this poster session is to present a study in progress involving analysis of the effects of using instructional games to teach science to elementary school students. The study as planned involves the following objectives and procedures.

1. Identification and acquisition of appropriate elementary science games.
2. Evaluation of selected games by classroom teachers.
3. Selection of specific games for classroom implementation.
4. Design of experimental situations that yield various kinds of data on the effects of selected games.
5. Analysis of the effects of using instructional games to teach science to elementary school students.

It is hoped that the results of this study will be helpful in guiding teachers about how instructional games are best used. The kinds of science learning (cognitive, low or high; affective; science perception; etc.) best promoted by specific games or the kinds of classroom transactions fostered are among effects that may be examined in this study and of value to the teachers.

At a minimum this investigation will provide a research-based examination of an often overlooked teaching strategy - instructional games.

Session C-9

EMERGING TRENDS FROM A DECADE OF SCIENCE EDUCATION RESEARCH: 1976-1986

Saouma BouJaoude
University of Cincinnati
Cincinnati, OH 45221

The purpose of this paper is to survey, categorize, and identify trends in science education research in the past 10 years, from 1976 to 1986, and to propose meaningful patterns of research during this period. Two major science education publications are used in this effort: The Journal of Research in Science Teaching and Science Education.

Four different procedures were used to attain the goal set for this effort. First, categories and subcategories of science education research were identified through a review of the literature. Second, the abstracts in the two journals employed were read and sorted according to the predetermined categories. New categories were created in the process if articles did not fit one category or the other. Third, when an abstract left doubt as to its placement, the original source was read to make the decision. Fourth, graphs and tables were drawn to identify patterns and trends in the research surveyed.

Six major trends in science education research are identified: Piagetian psychology is the dominant paradigm in science education research, but information processing psychology is gaining ground as a research alternative; research reports are shifting from describing events and reporting effects of treatments to attempting to investigate why and how events cause the effects they do; quantitative research is the dominant research methodology, but ethnographic research is being used more frequently; meta-analysis has emerged as a new technique for summarizing research; the use of multivariate research designs is increasing; and interest in international science education is increasing.

The four following recommendations are offered: there is a need for research on: (1) teacher planning, thinking, improvisation, and examining the differences between expert and novice science teachers; (2) classroom interactional processes; (3) the environmental influences of the home, classroom, and significant others on science learning; and (4) problem solving in the various science subjects and problem-solving instruction.

NEEDED CHANGES IN SCIENCE/MATH TEACHER EDUCATION

Jack Easely
University of Illinois-Urbana-Champaign
Champaign, IL 61820

Deborah Trumbull
Cornell University
Ithaca, NY 14853

An elementary teacher educator argues that, despite the recommendations of recent national organizations, elementary school teachers do not need more course work in science and/or mathematics in order to facilitate the development of their pupils' critical thinking skills in science and math. Rather, more coursework will likely have the opposite effect, hindering teachers' comfort at letting their pupils conduct inquiry in science and math. Teachers who have moved to encourage student inquiry are influenced more by commercial materials and courseware than by pronouncements from recognized schools of education.

A secondary science teacher educator argues that a primary task of teacher education is to challenge students' assumptions about the preparatory functions of high school science classes. Future teachers need to develop their own practical knowledge of teaching and learn to use this knowledge to structure work in science that meets the conditions of true inquiry, guided by the concerns of students. These changes involve a reconceptualization of the notion of control, a recognition of the professional knowledge of teachers, and an honoring of the concerns and responsibility of pupils.

GOALS AND COMPETENCIES FOR PRECOLLEGE STS EDUCATION: RECOMMENDATIONS BASED UPON RECENT LITERATURE IN ENVIRONMENTAL EDUCATION

Peter A. Rubba
Randall L. Wiesenmayer
The Pennsylvania State University
University Park, PA 16802

What constitutes effective precollege STS education which aims to help learners develop the knowledge, skills and affective qualities needed to take responsible social and political action on STS issues? The STS education literature is sparse when one seeks curricular and instructional guidance to use in addressing this question. Notwithstanding, there is a substantial body of recent literature in the area of environmental education which has implications for precollege STS education approached from this social responsibility viewpoint. In particular, a recent set of studies on responsible environmental behavior by Klingler, Hines, Ramsey and Sia confirm the value of, and so the need for, issue investigation and action-oriented instruction if learners are to take actions on STS issues. These studies also suggest a goal structure for STS Education modeled after one proposed for environmental education by Hungerford, Peyton and Wilke. That STS goal structure would include four levels: Level I, the STS Foundation Level; Level II, the STS Issue Awareness Level; Level III, the STS Issue Investigation Level; and Level IV, the STS Action Skills Development Level. In this paper the nature of curriculum and instruction at each of these four goal levels is suggested and 52 learner competencies are proposed under the various goal structure levels.

Session C-10

A WORKSHOP ON SELECTED TECHNIQUES FOR THE EVALUATION OF SCIENCE TEACHER EDUCATION PROGRAMS

Jerry B. Ayers
Tennessee Technological University
Cookeville, TN 38505

It was recently noted that assessment and feedback is a key for the improvement of teacher preparation programs. However, it was further noted that there is a dearth of models and systems for carrying out such evaluation activities. In an effort to improve teacher education programs, the State of Tennessee has established a Center for Teacher Education Evaluation at Tennessee Technological University. The purpose of the Center is to develop models and other materials that can be used in the assessment and refinement of teacher preparation programs.

Based on the activities of the Center, a workshop will be conducted that is designed to provide participants with some of the needed skills to carry out evaluations. At the conclusion of the workshop it is expected that the participants will have a better knowledge of the sources of information on program evaluation and developed skills in such areas as the use of flow charts in analyzing instructional and evaluation problems, selection of evaluation techniques and devices, and designing original program evaluation devices. Participants will be introduced to the essential design characteristics of an evaluation model followed by an introduction to a six part evaluation model that has been successfully used to evaluate such diverse programs as those designed for teachers and for electrical engineers. In the second phase of the workshop, participants will have the opportunity to begin the design of a model or system that will be of practical use in evaluating innovative programs for the preparation of science teachers. Throughout the workshop, emphasis will be on practical involvement in the development of useful tools.

At the conclusion of the workshop, the participants will have achieved familiarity with a model that can be useful in the evaluation of programs for the preparation of science teachers. In turn, their knowledge can be applied to the development of evaluation models useful in their home institutions or agencies.

Session C-11

NARST ROUND TABLE

Report from the National Conference on Technology and Teacher Education: Recommendations for Action

SueAnn Ambron
Apple Computer, Inc.
Cupertino, CA 95014

Carl Berger
University of Michigan
Ann Arbor, MI 48109

Marcia Linn
University of California at Berkeley
Berkeley, CA 94720

Karen Sheingold
Bank Street College of Education
New York, NY 10025

This round table reports the results of the National Conference on Technology and Teacher Education held August 5-8 in Monterey, California, relevant to Science Education. Participants were 30 deans of Schools of Education from leading research universities across the United States, the leaders in Teacher Education and Technology at the same institutions, and leaders in software development and research on technology and education, and leaders from Apple Computer. Copies of the conference report will be available before the meeting.

The conference was organized in response to a need for increased collaboration among the diverse groups interested in making effective use of computer-based technology in education. As a result, the conference brought together representatives of software development, technology research, teacher education, and educational leadership. Together these individuals shared information about the successes and concerns that they had in the field. This process was facilitated by numerous small group discussions, software demonstrations, presentations from leaders in technology and in technology and teacher education.

The primary recommendation emanating from the conference was a realization that partnerships and other collaborative arrangements are necessary to respond to these important problems. A number of administrative arrangements were suggested, including industry, university and pre-college consortia, working together to achieve common goals. Implementing this suggestion for science education will be the primary focus of the round-table discussion.

Session C-12

INFORMAL DISCUSSION

with

NARST President

JRST Editor

Session C-13

THE THEORY OF REASONED ACTION: CAN IT BE USED TO PREDICT AND UNDERSTAND THE BEHAVIOR OF SCIENCE TEACHERS AND STUDENTS?

Thomas R. Koballa, Jr.
Frank E. Crawley
The University of Texas at Austin
Austin, TX 78712

Robert L. Shrigley
The Pennsylvania State University
University Park, PA 16802

The purpose of the symposium was to outline the Theory of Reasoned Action as proposed by Ajzen and Fishbein and provide evidence that suggests that the theory is a viable approach to be used by science educators in predicting and understanding the behavior of science teachers and students. Three interrelated presentations constituted the symposium.

The model derived for the Theory of Reasoned Action is predicated on the assumption that most human behavior is to some degree volitional in nature and hence guided by the behavioral intention of the individual. In the model it is supposed that the intention to perform a certain behavior is a function of the weighted personal component and the weighted social component. Called "attitude toward the behavior," the individual's feelings about performing the behavior form the personal component and a function of the expected consequence of performing the behavior and the evaluations of these consequences. The social component, called the "subjective norm," is the person's perception of the social pressures to perform the behavior. It is a function of normative beliefs regarding the performance of the behavior and motivation to comply with these beliefs.

The steps to follow in constructing a questionnaire to measure the variables that function as determinants of behavior according to the model are:

Step 1. Define the behavior of interest in term of action, target, context, and time elements.

Step 2. Define the corresponding behavioral intention.

Step 3. Define the corresponding attitude and subjective norm.

Step 4. Elicit salient outcomes and referents.

Step 5. Define behavioral beliefs, outcome evaluations, normative beliefs, and motivation to comply.

Steps 1 through 3 permit the prediction and explanation of behavior at a general level. To obtain substantive information about the cognitive foundations underlying the behavior, it is necessary to complete the remaining two steps. Step 4 is completed by having a representative sample of the population of interest respond to an open ended questionnaire. Information regarding salient outcomes and referents obtained from the open ended questionnaire are used in the construction of behavioral belief, outcome evaluation, normative belief, and motivation to comply items. These items along with items to assess behavioral intention, attitude toward the behavior, and subjective norm are found on a final questionnaire.

The findings of two studies provide support for hypotheses derived from the model. In one study, the intentions of female junior high school students to enroll in at least one elective physical science course in high school were found to be a function of both their attitude toward performing the behavior and subjective norm. Attitude toward performing the behavior was found to carry more weight than subjective norm in the multiple regression on behavioral intention. In contrast, academic ability, science grades, and attitude toward science failed to predict behavioral intention. In the second study, the intentions of eighth grade students to enroll in a ninth grade science course (assuming it to be an elective) were also found to be related to attitude toward the behavior and subjective norm. Attitude toward the behavior and subjective norm considered collectively were found to be better predictors of intention than either variable considered separately. Of the five external variables tested, only SRA scores were found to be significant predictors of intention to enroll in a ninth grade science course.

Session C-14

STUDENT ESTIMATION ON LINEAR AND LOGARITHMIC SCALES USING MICROCOMPUTERS

Carl F. Berger
Paul Pintrich
Paul Stemmer
University of Michigan
Ann Arbor, MI 48109

The problem of estimation is a general problem solving task that has cognitive consequences for students. Forty junior high school students were asked to solve two types of estimation problems (a linear task and a logarithmic estimation task) using a microcomputer simulation. Results showed that performance on the linear scale could be described by a general learning curve with improved performance over time. The logarithmic scale results did not show the same improvement over time, rather there was more complex interaction with target number and position number. When multivariate analysis was used, the position of the target was found to be a major variable. While students became more efficient learners as measured by the time used to estimate, students used the ends of the scales, logarithmic or linear, to help in estimation. Students learned quickly and, given the nature of the logarithmic task, performed well. The results are discussed in terms of students' knowledge of logarithmic scales and their general strategy for problem solving. Implications for teaching science using microcomputers to increase skill and shorten instructional time as well as science curriculum development are explored.

EFFECTS OF MODES OF COMPUTER-ASSISTED INSTRUCTION ON CONCEPTUAL UNDERSTANDING AND ACHIEVEMENT OF COLLEGE STUDENTS EXHIBITING INDIVIDUAL DIFFERENCES IN LEARNING

Paul Rowland
Carol L. Stuessy
New Mexico State University
Las Cruces, NM 88003

The purpose of this study was to determine the effects of two modes of computer-assisted instruction, simulation and tutorial, upon the ability of preservice elementary teachers to understand relationships between a number of concepts dealing with home energy. A number of instruments measuring various dimensions of learning style differences were administered to ascertain which learning style construct(s) interacted with mode of instruction to predict conceptual understanding and scores on an achievement test.

Results of this study indicate that a number of learning style variables interact with mode of computer-assisted instruction to predict conceptual understanding and achievement regarding home energy concepts. Particular learning style variables interacted with mode of instruction to predict lower- and higher-level understanding of concepts.

Implications of this research involve remediating and/or providing for individual differences in learning with both modes of computer-assisted instruction.

THE EFFECT OF MICROCOMPUTER ASSISTED INSTRUCTION ON ACHIEVEMENT IN HIGH SCHOOL CHEMISTRY

Burton E. Voss
Zelpha Ayoubi
University of Michigan
Ann Arbor, MI 48109

This study was conducted to investigate the effect of microcomputer assisted instruction on achievement in chemistry in a selective urban high school. Five classes consisting of a total of 125 students participated in the study. Seventy-seven were in the experimental group and 48 in the control group. The treatment of the experimental and control groups was identical in the following respects:

1. Both groups were taught by the same teacher.
2. Both groups were taught the same chemistry material.
3. Both groups were exposed to microcomputer programs from different sources as a part of the teacher's instruction (demonstrations, simulations).
4. Both groups took the same tests.
5. Both groups had the opportunity to use the modified computer programs outside the classroom period.

The treatment varied between the groups in only one way. The experimental group students used the modified microcomputer programs as a part of the instructional process while the control group students attended only teacher's lectures during those times.

Seven achievement measures were analyzed across treatment, general and mathematical abilities, and time on computer. Four of the seven measures were the unit tests used to assess students' achievement after each of the four units was completed. The other three measures were: the comprehensive semester test assessing the students' achievement from the first three units; the post-test, the ACS-NSTA

High School Chemistry Test (Form S, 1981), administered at the end of the semester; and gain scores, the difference between the pre-test and the post-test scores. Those three achievement measures were considered as a measure of the overall achievement.

Findings from the study were: Students spending half their classroom instruction time studying chemistry from microcomputer programs reached the same level of achievement as students receiving instruction only from the classroom teacher. Some results favored the control group because school policy gave students access to the computer programs for after school practice.

The amount of time spent on the computer was significantly related to achievement in chemistry for the experimental group students. High amount users scored significantly higher than did low amount users. However, the amount of time spent on the computer did not make significant differences in achievement between similar ability students although the high amount users scored higher. Medium ability students gained significantly more from the amount of time on the computer than low or high ability students.

More than half of the students in both the experimental groups felt that microcomputers were helpful as instructional tools.

Teachers should be selective in the way they use the microcomputers and the programs associated. Evidence from the kind of program (drill and practice), the kind of student (ability level) and the way classes are organized to work on the computer have influenced the achievement of students in this study.

LEARNING FROM COMPUTER SIMULATIONS

James R. Okey
The University of Georgia
Athens, GA 30602

Ronald G. Oliver
Western Australian College of Advanced Education
Churchlands, Western Australia 6018

Computer simulations present some simplified models of reality that can be observed and altered. As such they allow learners to study cause and effect relationships, to make predictions, to test hypotheses, to gather data, and to draw conclusions. In addition to these learning advantages, simulations offer teaching advantages as well -- allowing interaction with difficult, dangerous, expensive, or time-consuming events.

Many simulations, however, have value not because of the direct knowledge or skills that they teach. Rather, their worth is judged to be what students are able to do subsequent to their study. For example, there is little intrinsic worth in the skills of managing a buffalo herd or assembling a raft on a computer screen in order to escape an impending flood. The value of simulations such as these is thought to relate to the general skills students develop which are then transferable to other tasks in school or in life.

This study examined the effectiveness of a computer simulation in promoting the skills needed to be successful with it and whether these skills were then able to be applied in related problems.

Students from three different schools used a computer simulation over a period of six weeks. In the first school the students worked in pairs, each sitting in front of the terminal and alternatively taking turns in responding to the simulation tasks. At the second school students worked in groups of four. Students in the third school were directed to work as pairs at the computer terminal as space and time permitted. In this instance only a single computer was used over a number of school days so that all students had an opportunity to interact with the computer simulation. In the first two schools, the students were taken to a computing laboratory on a nearby campus where all students in the class simultaneously worked on the simulation. The simulation requires students to cooperatively work with one another in order to escape an impending disaster. The simulation, according to stated objectives, promotes "reading comprehension, communication, cooperative behavior, and problem solving."

Students completed four measures -- one before using the simulation and three afterwards. The measures tested logical thinking, attitudes toward computing, knowledge acquired during the simulation, and ability to transfer simulation skills to new topics. Tape recordings of selected student groups and interviews were also used to analyze student participation and reactions.

Differences in attitudes toward computing were found. Students working with the computers in laboratories significantly outscored the third group that used the simulation less frequently in their own classroom. Students in the two lab groups that used the computer simulation the most also, and not surprisingly, acquired the most knowledge about the simulation skills. Transfer to new tasks, however, was not related to the amount learned in the simulation. Instead, transfer scores were associated most strongly with logical thinking ability, not knowledge acquired during the simulation itself. Cooperative behavior increased during the time students worked -- initial arguments and non-cooperation ultimately gave way to smoother working groups as the need for harmonious actions became apparent.

Session C-15

Outstanding NARST Paper

JRST AWARD

Session C-16

A PAPER SET: CROSS-CULTURAL RESEARCH IN SCIENCE EDUCATION AN ASIAN PERSPECTIVE

(Indonesia, Japan, Philippines, Taiwan)

Joseph P. Riley, II
Chao-Ti Hsiung
Hsiao Lin Tuan
Elisabeth H. Charron
University of Georgia
Athens, GA 30602

As researchers studying science education, most of us seek to describe particular learning settings and to identify the major processes which affect learning outcomes there. In the interest of asking a "researchable question," we generally confine each investigation to given types of schools, teachers, students and courses. For example, a researcher might choose to study some aspect of chemistry instruction by novice teachers in upper secondary classrooms in urban communities. As we select appropriate boundaries for our research, we often choose to work within a particular cultural milieu, for example American suburbs or rural communities. While such boundaries are sensible from a control-of-variables point of view, the cultural setting itself is sometimes a variable of interest. Cognitive, social, and educational processes often vary from one culture to the next. When the cultures are sufficiently distinct, as for example when we compare the United States with Indonesia, so-called universal understandings of given classroom processes, or even students' cognitive development, may prove to be more culture-bound than global. For this reason, cross-cultural looks at educational settings are often valuable.

In the present paper set, the authors take a multi-cultural look at selected processes of interest to science educators. Two papers look at student characteristics from a cross-cultural perspective. The first of these investigates the development of logical thinking abilities in the Philippines and Indonesia. The second paper examines the same variable and its relationship to process skills and achievement in Taiwan, and draws comparisons with results obtained in other countries. In the third and fourth papers, teacher strategies are the focus. The third paper compares instructional and motivational strategies employed by teachers in the U.S. and Taiwan. The fourth takes an in-depth look at patterns of teacher behavior observed in Japanese elementary science classrooms, and investigates their cultural basis.

Throughout the paper set an effort is made to (1) accurately describe selected aspects of science education in each country, (2) identify unique or characteristic aspects of each culture, (3) identify connections between educational processes and the particular culture, and (4) make recommendations for improving science education across cultural settings.

THE DEVELOPMENT OF LOGICAL THINKING SKILLS AMONG INDONESIAN AND PHILIPPINE STUDENTS

Joseph P. Riley, II
University of Georgia
Athens, GA 30602

Dr. Subiyanto
IKIP
Malang, Indonesia

Laurena G. Chuapoco
Marikina Institute of Science and Technology
Philippines

The purpose of these status studies was to begin mapping out the development of logical thinking skills of Indonesian and Philippine secondary and college level students. The development of valid and reliable pencil and paper measures of logical thinking have made it possible to more easily sample and assess student development of these skills. The Philippine data are part of a four year longitudinal study to investigate changes in cognitive development over four years of high school. Data have been collected on the same students for the past three years.

The Indonesian study used similar procedures to trace student cognitive development at the college level. This study was initiated in 1985 and is in its second year. The results of these studies can provide educators an indication of when students of their respective countries are likely to exhibit the thinking skills associated with the formative stages of development. The results have implications for teachers and curriculum decision makers in these countries.

RELATIONSHIPS AMONG SCIENCE PROCESS SKILLS, LOGICAL THINKING ABILITIES AND SCIENCE ACHIEVEMENT OF SENIOR HIGH STUDENTS IN TAIWAN

Chao-Ti Hsiung
Hsiao Lin Tuan
University of Georgia
Athens, GA 30602

Improvement in student process skills and logical thinking ability is a natural goal of science education.

The purposes of this study were: (1) to identify process skills and logical thinking ability of senior high students in Taiwan, (2) to determine the relationship among process skills, logical thinking abilities and science achievement, (3) to compare process skills/logical thinking ability among Japan, U.S., Philippine, and

Taiwan students, and (4) to speculate on the influence of different cultures on development of logical thinking abilities. The sample consisted of 300 tenth grade students (six classes) from Taiwan. The classes represent high, middle, and low achievement students. Two criterion measures were used. Scence process skills were measured using the Test of Integrated Process Skills (TIPS). Logical thinking was measured using the Group Assessment of Logical Thinking (GALT). Science entrance exams and results of monthly examinations were used as measures of science achievement. The results can be used by teachers to better understand the abilities of their students in order to achieve effective teaching. It is also a reference point to improve science curriculum and to facilitate cross-cultural communication in science education between Taiwan, the United States, and other countries.

A CROSSCULTURE QUALITATIVE STUDY OF INSTRUCTIONAL AND MOTIVATIONAL STRATEGIES USED BY EXPERT AND NOVICE TEACHERS IN THE U.S. AND TAIWAN

Hsiao Lin Tuan
Chao Ti Hsiung
Russell H. Yeany
University of Georgia
Athens, GA 30602

Much recent attention has been given to differences that exist between learning and teaching in different cultures. In fact, some of the variations that exist in technological advances and world marketplace advantages have been attributed to cultural differences that are expressed in the instructional setting. Instructional and motivational techniques are powerful variables in learning. Since effective instructional and motivational techniques are difficult to master, differences can exist between experienced and beginning teachers.

The purpose of this paper is to report on variations that exist in U.S. and Taiwan experienced and beginning science teachers with regard to instructional strategies which include lesson planning, content teaching, questioning, lab activities, and pupil evaluation; and motivational strategies which include stimulating learning, maintaining affect, communicating, and providing feedback. Finally, the interaction of culture and experience in regard to instruction and motivating students will also be estimated.

The study used a qualitative design to collect in-depth information. Two public middle schools, one in Georgia and one in Taiwan, were selected to represent two different cultures. Four general science classes at each school served as the data sources for the study. Two science teachers represented the beginning teachers while two others were experienced teachers at each site. Data are in the form of field notes and checklists based on direct observations by the researchers.

The amount of time in each classroom equaled 20 days. In addition, interviews and questionnaires regarding perceptions of students and teachers are part of the main data set. The results will be presented as responses to the purpose of the study regarding the culture and experiences versus beginning difference. The major assertions under each category will be able to stand the test of validity by being supported by the majority of data sources pertaining to it.

The comparison between these two can provide specific examples of the application of teaching strategies which are useful in teacher training and further research. The comparison of experienced and beginning teachers helps to identify how the teaching experience influences the use of strategies and can be helpful with pre-service and novice teachers in avoiding trial and error approaches to settling on effective strategies.

TEACHER BEHAVIOR IN JAPANESE ELEMENTARY SCIENCE CLASSROOMS

Elisabeth H. Charron
University of Georgia
Athens, GA 30602

The purpose of this study was to provide a detailed description of teacher behavior in elementary science classrooms in selected Tokyo elementary schools in order to (1) identify teacher behavior patterns which may be associated with cross-national student achievement differences, and (2) explore the relative importance of culture-based vs. personological influences on teachers' behavior. The author was a participant-observer in three Tokyo elementary schools for one month. During this period, 39 elementary science lessons taught by 13 teachers were observed. Teacher behaviors were documented in field notes and videotapes of the lessons. In addition, interviews were conducted with selected teachers; records such as lesson plans and teacher goal statements were gathered, and additional observation was carried out during teachers' meetings, science inservice programs, school assemblies, and non-science lessons. The field data were supplemented by questionnaire results obtained from 119 Tokyo-area elementary teachers representing ten additional schools. Target teacher behaviors observed included planning, questioning, direction-giving, management of instruction for various group sizes, and task flow management. Some consistent patterns of teacher behavior were identified, such as the frequent use of content-related questions compared to procedural questions, and a preference for small group activities during science instruction. However, longer term observation of a more diverse sample of instructors will be necessary before general conclusions can be drawn about elementary science teachers' classroom behavior in Japan.

Session C-17

A PAPER SET: A REPORT ON THE IMPLEMENTATION PROCESS AND EVALUATION OF AN EXEMPLARY ELEMENTARY SCIENCE PROGRAM

A Longitudinal Assessment of Students' Attitudes Toward Science During a Three Year Curriculum Implementation Project

Thomas Gadsden, Jr.
Richardson Independent School District
Richardson, TX 75081

William C. Kyle, Jr.
The University of Connecticut
Storrs, CT 06268

Ronald J. Bonnstetter
University of Nebraska
Lincoln, NE 68512

This three-year longitudinal study was designed to assess and analyze the attitudes toward science of students before and during a three year implementation of a modified SCIIS curriculum. The results of this study substantiate the fact that students have a preference for process-approach science. Significant attitudinal differences were observed between SCIIS and non-SCIIS students for the pre-post comparisons. Attitudinal gains were maintained as students progressed from the first year of a process-approach science curriculum to the second and third years.

While the entering behaviors and perceptions of SCIIS and non-SCIIS teachers are very similar, over 45% of all first year SCIIS students during the three-year project chose science as either their first or second favorite subject in school. After three years, 43% of the students still make such claims. Less than 20% of all non-SCIIS students possess such preferences.

The data reported in this paper set appear to suggest that the nature of process-approach science in conjunction with a well articulated inservice program allows SCIIS teachers to portray a much more positive and exciting image of science and scientists. Implications of these results for inservice and preservice teacher education will be provided.

A Longitudinal Assessment of the Effect of Process-Science on Student Achievement

William C. Kyle, Jr.
The University of Connecticut
Storrs, CT 06268

Ronald J. Bonnstetter
University of Nebraska
Lincoln, NE 68512

This component of the project evaluation was designed to assess the differential impact (if any) of one, two, or three year(s) of process-approach science on student achievement. During the 1985-86 academic year, the Iowa Tests of Basic Skills (ITBS) Complete Battery with the Social Studies and Science Supplement was administered to 2,363 sixth grade students. Each student was completing either one, two, or three year(s) of involvement with a process-approach science curriculum (a modified SCIIS curriculum).

In order to compensate statistically for pretreatment differences in achievement, students' third grade test scores on the Comprehensive Test of Basic Skills (CTBS) were selected as a covariate. Data were also analyzed by student gender. Correlations are provided for students' achievement and their attitudes toward science.

A Longitudinal Assessment of Teachers' Attitudes Toward Science in Process-Approach vs. Traditional Science Classes

Ronald J. Bonnstetter
University of Nebraska
Lincoln, NE 68512

William C. Kyle, Jr.
The University of Connecticut
Storrs, CT 06268

This three-year longitudinal study was designed to assess and analyze the attitudes toward science and the general characteristics of teachers instructing first- and second-year SCIIS classes compared to teachers in non-SCIIS classes. Comparisons with national norms and teachers of exemplary programs are also drawn. Although entering behaviors and perceptions of SCIIS and non-SCIIS teachers are very similar, the comparison to corresponding student perceptions leaves little doubt as to the importance of proper program installation.

This study demonstrates that the success of any inquiry based, process-approach program rests heavily on the effectiveness of inservicing and the creation of an on-going administrative support component. The comparison of SCIIS and non-SCIIS teacher characteristics clearly indicates that a properly inserviced program can go a long way toward resolving the apparent Catch-22 of lack of interest and preparation among elementary science teachers, thus creating a well-articulated delivery system and a meaningful science experience for students. Additional implications of these results for inservice and preservice teacher education will be provided.

Session C-18

THE DIFFICULTY OF THE LOGICAL SYLLOGISM: IS IT ENCODING OR COMBINING?

Dorothy A. Petrushka
Somerset County College
Bridgewater, NJ 08807

A study was conducted with 36 students enrolled in an introductory biology course. The purpose of the study was to discover the role of linguistic content in solving logical syllogisms. In particular, it was of interest to determine the effect on each of the two sub-tasks of the syllogisms, which are encoding the premises (what it means to the subject), and combining the premises to reach valid conclusions (a logical task). Two operations were selected, the conditional (implication) and the inclusive disjunction, both of which have presented much difficulty to young adults. Two contents were used, symbolic and familiar. Each of the four tasks were split into two sub-tasks. The encoding tasks were completed before the combining tasks were begun. For the combining tasks, appropriate encoding was provided.

Results showed that familiar content impacts largely on encoding for the conditional syllogism. Success was significantly greater with familiar content. No (significant) effect was apparent for the logical portion of this task. Familiar content had a positive effect on encoding and combining of premises for the inclusive disjunction operation. An analysis of Ss successes with the conditional showed that if one could encode, then one could combine premises. However, non-encoders demonstrated much success with combining when the correct encoding was provided. Nevertheless, encoding success with the inclusive disjunction operation did not guarantee success with the logical portion of the task. Some other elements seem to be hindering.

Several implications for science teaching are evident, including, among others, the careful construction of problems, with consideration of content, context, and presentation manner. Attention should focus on the development of reasoning skills which may be universally applied.

THE DEVELOPMENT OF AN INSTRUMENT TO MEASURE THE PROCESSING OF SPATIAL-SYMBOLIC INFORMATION

Donna F. Berlin
The Ohio State University at Newark
Newark, OH 43055

Arthur L. White
The Ohio State University
Columbus, OH 43210

The purpose of this study was to develop a pencil and paper measure of the understanding of spatial and symbolic arrangements (The Spatial-Symbolic Processing Test). This instrument is needed to assess the abilities of children to recognize, extend, generate, and/or construct designs, patterns, and sequences from figural, numeric, and textual events.

A 42 item instrument was administered to a sample of 106 third, fourth, and fifth grade children in a rural elementary school. Descriptive statistics were computed to summarize the significance of the relationships of the responses, student grade level, and gender. A principle components analysis was used to assist in the identification of the underlying constructs represented by the item responses.

The five resulting scales and corresponding internal consistency reliabilities from these data are:

Figural Analogy, Alpha = 0.81
Monotonic Progression, Alpha = 0.67
Figural Pattern, Alpha = 0.76
Rule Application, Alpha = 0.72
Rule Identification, Alpha = 0.60

Grade level was significantly correlated with Figural Analogy (r=0.21, p<.04) and with Rule Application (r=0.21, p<.04). These scales involved association or correlational reasoning. On both of these scales children at the higher grade levels did better.

Gender was significantly correlated with Rule Identification (r=0.31, p<.002). The multivariate gender effect was significant (p=.01) with the girls doing better than the boys. The univariate analyses reveal that the Rule Identification scale was the primary factor responsible for this effect. This scale is comprised primarily of items which require the subject to determine the continuum represented by two words and select the word that comes next. The girls were better at this task than were the boys.

The resulting scales need to be expanded by developing additional items homogenous to the clusters identified in this research. These scales will be validated through use in correlational and experimental studies in order to establish accurate, precise indicators of childrens' abilities to comprehend figural, numeric, and textual arrangements. These scales (The Spatial-Symbolic Processing Test) will facilitate the exploration of relationships between the learner's ability to recognize and extend arrangements of designs, patterns, and sequences and the selection and sequencing of science and mathematics instructional activities.

KNOWLEDGE STRUCTURE ORGANIZATION IN NUTRITION STUDENTS

Marcy J. Leeds
Slippery Rock University
Slippery Rock, PA 16057

The objective of this research was to characterize mental models of the energy metabolism system in order to better understand how nutrition students organize and access knowledge. The subjects for this study were 40 undergraduate students who had previously completed a basic nutrition course which included a section on energy metabolism.

In order to characterize their mental models, these students were interviewed about their ideas and understanding of energy metabolism. Transcribed interviews were analyzed by Ericsson and Simon's methods of protocol analysis.

First, the investigator developed a standard model of energy metabolism to use as a measuring instrument. This proposed model was broken down into nodes and links, and then further divided into two parts, the Transformation Section and the Utilization Section. Using Ericsson and Simon's methods, each learner's interview was encoded into a network model. These models were then broken down into nodes and links.

The majority of students accessed information from long-term memory (LTM) through organized concepts that were not connected. The learners had trouble linking these concepts to one another to form a system or schema. Nodes were identified more frequently than links. Nodes and links in the Utilization Section which required concrete thinking were identified more frequently than nodes and links in the Transformation Section which required operational thinking.

The findings suggest that nutrition educators consider instructional methods that offer the students concrete learning experiences and tangible interactions with the system being studied. Furthermore, instructional methods that will encourage students to store information in and access information from LTM in terms of schemata containing links between organized concepts need to be incorporated into nutrition education strategies.

Session C-19

LINKING THREE RESEARCH AGENDAS OF SCIENCE TEACHING: STUDYING SCIENCE, CLASSROOM IN SCIENCE, COMPUTERS IN SCIENCE

William G. Holliday
Julie P. Sanford
Joseph Krajcik
University of Maryland
College Park, MD 20742

The goal of the symposium is to stimulate discussion between the audience and the three participants focusing on separate research programs which are linked to a common processing principle of cognition. The three research agendas are: (1) student studying and science teaching, (2) academic work in the science classroom, and (3) learning science concepts through computer assisted instruction (CAI). Presenters will describe their research program in science teaching by linking their working model to a common cognitive principle based on information processing. The application of this principle will be the focal point of the presentations and the subsequent discussions with the audience. This principle is stated as follows:

> Students' construction of mental structures (propositional network or schema) requires an interactive processing of prior knowledge with newly presented information. That is, construction requires students to process prior "domain-specific" knowledge while using "task-specific" learning strategies with the goal of accomplishing specific work assigned by their teacher. Thus, it follows that students should be required by their science teachers to engage in comprehension strategies rather than strategies focusing on the memorization of new information or the mere application of routine algorithms to familiar context.

Session C-20

IMPROVEMENT OF SCIENCE TEACHING PRACTICE THROUGH THE USE OF COACHING

Kenneth Tobin
Florida State University
Tallahassee, FL 32306

Mariona Espinet
Pam Sloan
Steven Byrd
Nancy Davis
University of Georgia
Athens, GA 30602

The symposium will focus on the problems that face science educators in trying to improve science teaching practice. The participants will present the results of research on two coaching models which were used with middle and high school science teachers. The results of the studies highlighted the importance of teachers' knowledge and beliefs in shaping how the curriculum is implemented in their classrooms. Other factors which influenced the implemented curriculum will also be discussed in the context of the difficulties that teachers face in improving their teaching even when they have identified areas in which they would like to improve.

The first coaching model involved two teachers coaching one another. In the high school study one of the teachers was experienced, but lacked relevant content area knowledge and had severe management problems in his classes. The second teacher was relatively inexperienced, but had a stronger science background and was able to manage and instruct her students in a satisfactory manner. An interpretive research methodology was used to investigate how these teachers taught their classes, their beliefs about science teaching and learning, and the processes involved in peer coaching.

Two middle school teachers also used the first coaching model. In this case both teachers had weaknesses in the content areas they were teaching, but only one of the teachers acknowledged the weaknesses. This study also investigated the role of teachers' knowledge and beliefs in shaping what they do in the classroom and how they perform as a coach.

The second coaching model investigated in this study involved the use of a master science teacher who was external to the school. One male middle school teacher was coached by a female science teacher for the duration of the study. The investigation provided insights into problems associated with teachers identifying their own strengths and weaknesses, and resistance to change.

Each of the studies highlighted the importance of teachers' beliefs about teaching and learning. The symposium will also discuss methodological factors associated with inferring beliefs and intuitive knowledge of teachers.

Session C-21

THE GALT: A MEASURE OF LOGICAL THINKING ABILITY OF 7TH THROUGH 12TH GRADE STUDENTS

Betty L. Bitner
Southwest Missouri State University
Springfield, MO 65804

The purpose of this study was to determine the level of reasoning of a convenience sample of all seventh through twelfth grade students (N = 156) in a consolidated school district in rural Arkansas prior to the introduction of a thinking program in which logical thinking is one component. Four research questions were investigated: (1) What percentage of seventh through twelfth grade students are formal operational thinkers as measured by the Group Assessment of Logical Thinking (GALT)? (2) Are there significant differences in the level of thinking as measured on the GALT among seventh through twelfth grade students? (3) Are there gender differences in logical thinking ability of seventh through twelfth grade students as measured by the GALT? (4) What are the underlying differences among seventh through twelfth grade students classified as formal, transitional, or concrete operational? The twelve-item abbreviated form of GALT was selected to measure the reasoning level of the sample. Both construct and criterion-related validities and reliability have been established by the authors of the GALT. In the present study, the test analysis resulted in a KR-20 reliability coefficient of .82.

The intercorrelation matrix for the six modes of reasoning resulted in correlation coefficients ranging between .17 and .78. The highest correlation coefficients were found between the GALT total score and proportional reasoning (.71), probalistic reasoning (.78), and combinatorial reasoning (.70). The range of the principal components factor analysis was .36 to .82 with all items, except the two which measure conservation, loading on Factor 1. The percentages of each reasoning level for the total sample were 11% formal, 19% transitional, and 70% concrete. Significant differences at $\underline{p} < .01$ were found on the one-way analysis of variance for school in favor of senior high students, for grade level in favor of the tenth grade students, and between seventh and eighth grade students in favor of the eighth grade students. Significant gender differences were found for individual items of the GALT, but not for the GALT total. Males outperformed the females on the metal weights, a conservation problem, and squares and diamonds #2, a probabilistic reasoning problem, whereas females outperformed the males on the dance, a combinatorial reasoning problem. In addition, patterns were found for transitional and concrete operational thinkers who responded incorrectly to the answer and reason of Item 8 and Item 11 and only the reason of Item 16, Item 17, and Item 18. Only four formal operational thinkers responded incorrectly to Item 20.

The results of this study seem to indicate a hierarchy of formal operational levels, i.e., correlational reasoning, proportional reasoning, combinatorial reasoning, probabilistic reasoning, and controlling variables. This hierarchy was considered in the development of the intervention program for non-formal thinkers. The intervention program for non-formal operational thinkers consists of the use of tuning, of concrete physical models, of the inquiry approach, and of dissonance.

MAXIMIZING STUDENTS' LEARNING BY MATCHING TEACHING STRATEGIES TO THEIR COGNITIVE ABILITIES

Herbert G. Cohen
Arizona State University
Tempe, AZ 85287

The purpose of this investigation was to examine the effects of two different teaching strategies on students possessing different levels of cognitive abilities. The two strategies examined were:

1. providing instruction through purely verbal means
2. providing instruction using activities and manipulatives along with some verbal interactions.

The study was conducted in a junior high school in Mesa, Arizona. A battery of Piagetian-type tasks was individually administered to each student. The results from these permitted the identification of four groups, ranging from one comprised of subjects who possessed all the structures examined to one comprised of subjects who possessed none of the structures.

Four intact Earth Science classes took part in the study as did two science teachers. Each teacher taught two of the classes. All of the classes used the Heath Earth Science textbook and associated materials. Two units of study were taught: Rocks and Rock Cycles, and Weather. Each instructor taught one of their classes providing instruction using Strategy I and taught their second class Strategy II. For the second unit the teachers reversed the strategies used with each class.

After each unit of instruction an examination was administered. Each examination was comprised of a variety of questions: recall, evaluative, or interpretive.

Using the Spearman Rank Correlation Coefficient procedure it was determined that those subjects possessing a large number of cognitive structures tended to correctly answer a greater proportion of the evaluative and interpretive questions regardless of whether Strategies

I or II was used. Conversely, those subjects who possessed relatively few of the structures tended to answer a smaller proportion of these types of questions if Strategy II was used than when instruction was provided using Strategy I.

If teachers wish to have a large proportion of students successfully evaluate and interpret data, they should deliver instruction using strategies which take into account the cognitive abilities of their students.

TEACHING PROBLEM SOLVING TO UNIVERSITY GENERAL CHEMISTRY STUDENTS

David V. Frank
Ferris State College
Big Rapids, MI 49307

J. Dudley Herron
Purdue University
West Lafayette, IN 47907

The purpose of this experiment was to compare a problem-solving teaching approach with more traditional instruction in terms of students' subsequent achievement and problem-solving processes. This problem-solving approach, involving instruction in an overall general problem strategy, heuristics, and student work on new problems, was used in the small recitation sections of a large general chemistry course for an entire 16-week semester. There were 82 general chemistry students (mostly freshman science and engineering majors at Purdue University) who participated in this experiment. Students in the experimental sections significantly outperformed (p=0.034) control students on all of their examinations, but on test items that were problems their increased scores only approached significance at the 95% level (p=0.056). Twenty-nine students from these sections also participated in think-aloud interviews to assess their use of problem-solving strategies. Few clear-cut differences could be found here, where the experimental group used more generalizable representations, made fewer math errors, were more persistent, and evaluated their work more often than did control students.

Session C-22

ELEMENTARY SCIENCE TEXTBOOKS: THEIR CONTENTS, TEXT CHARACTERISTICS, AND COMPREHENSIBILITY

Eunice A. Greer
Linda A. Meyer
Lorraine Crummey
The Center for the Study of Reading
Champaign, IL 61820

The purpose of this paper is to present findings from a systematic analysis of elementary school science textbooks. Comparisons of content domains and vocabulary are presented for the Merrill (1982) and Silver-Burdette (1985) science programs, grades 1-5, as well as the fourth grade Holt (1980) and fifth grade McGraw-Hill (1974) texts. Analyses of how each publisher presents information, types of questions, and various text characteristics reveal striking differences between programs. Systematic comparisons of content domains between programs also reveal few instances of "inconsiderate" texts. Results are discussed in light of the differences found between programs regarding textbook content and opportunity to learn, greater amounts of text and activities within each program, teachers' probable uses of textbooks, long-term results of students' exposure to various textbooks, and the need for careful examination of materials in order to determine their quality.

SCIENCE INSTRUCTION IN KINDERGARTEN, FIRST, AND SECOND GRADE: A LONGITUDINAL DESCRIPTIVE STUDY

Robert L. Linn
University of Illinois
Champaign, IL 61820

Linda A. Meyer
C. Nicholas Hastings
The Center for the Study of Reading
Champaign, IL 61820

The purpose of this study was to measure the amount and type of science instruction longitudinally in three school districts. This paper presents preliminary descriptive findings from a study in progress in kindergarten, first, and second grade classrooms since 1983. Up to 10 observers observed each of up to 17 regular classroom teachers per cohort for one day each, approximately every three weeks, nine times each school year. Preliminary results show dramatic differences in the quantity and type of science instruction between

these three school districts, particularly from first grade on. Between district differences are much clearer than differences within districts. Kindergarten and first grade teachers show stable instructional patterns for the two years they were observed.

ASSESSING SCIENCE CONCEPT AND PROCESS ACQUISITION FOR FIRST, SECOND, AND THIRD GRADE CHILDREN

C. Nicholas Hastings
Linda A. Meyer
The Center for the Study of Reading
Champaign, IL 61802

Robert L. Linn
University of Illinois
Champaign, IL 61820

This paper describes development of four measures designed to assess students' understanding of science concepts in three content domains. One domain extends from home to school (plants), the second is traditionally presented in school (the three forms of matter), and the third is formally taught in school (motion). Motion is also of interest as a content domain because middle grade and older students have been shown to be confused about this concept. Items were developed for the three content domains using the following procedures. Textbooks used in three school districts participating in a longitudinal study of science concept acquisition were analyzed to produce lists of common content domains. Domains were selected that began at the first grade level and continued through the third grade level (plants), at second grade level and continued for at least two years (three forms of matter), and began after fourth grade (motion). Textbooks were coded to determine the common core curriculum for the three school districts. Concept, process and vocabulary analyses were then conducted for each content area. Items were then developed, piloted, and revised to measure concepts or processes on level or out of level in each category. The performance of the students on the four experimental tests will be reported by school and related to the background and the science coverage variables. Classroom performance will also be reported and related to the amount of time teachers devoted to science instruction.

PARENTAL REPORTS OF INTERACTIONS, EXPERIENCES, AND RESOURCES PROVIDED TO THEIR CHILDREN RELATED TO SCIENCE

Linda A. Meyer
C. Nicholas Hastings
The Center for the Study of Reading
Champaign, IL 61820

Robert L. Linn
University of Illinois
Champaign, IL 61820

This paper presents descriptive results from a longitudinal study of parental responses to questionnaires designed to capture how parents both formally and informally teach their children to view the world as well as the resources they provide to enhance this instruction. The questionnaires have two distinct parts, paragraphs that describe a scene parents are to respond to as if they did those things with their children, and an information section about activities, experiences, books, television shows, and activities children select. Response rates of over 80 percent for all parents in the study reveal substantial differences among parents on the paragraphs as well as differences for activities, books, resources, and children's choices.

THE INFLUENCE OF COGNITIVE REASONING LEVEL, COGNITIVE RESTRUCTURING ABILITY, DISEMBEDDING ABILITY, WORKING MEMORY CAPACITY, AND PRIOR KNOWLEDGE ON STUDENTS PERFORMANCE ON BALANCING EQUATIONS BY INSPECTION

John R. Staver
University of Illinois at Chicago
Chicago, IL 60680

Tom Jacks
Glenbrook North High School
Northbrook, IL 60062

Eighty-three (83) high school chemistry students were administered tests of cognitive reasoning level, cognitive restructuring ability, disembedding ability, working memory capacity, and prior knowledge before a learning segment on balancing chemical equations by inspection. After a four-day instructional segment utilizing direct teaching methodology, participants were given a posttest on balancing equations. Initial regression analysis indicated that a multicolinearity problem existed. Factor analysis and correlational data indicated that the reasoning, restructuring, and disembedding variables could be collapsed and redefined as a single restructuring variable. A hierarchial regression analysis was then performed, and the following conclusions were derived: (1) when prior knowledge alone is considered, students' understanding of chemical formulas significantly ($p < .05$) influences overall equation balancing performance; (2) when prior knowledge, restructuring, and working memory are considered, only restructuring ability significantly ($p < .05$) influences overall performance; (3) working memory capacity does not significantly ($p <.05$) influence overall performance but does on certain posttest items; and (4) prior knowledge and restructuring ability also significantly ($p < .05$) influence performance on certain posttest items. Discussion includes the rationale for identifying the collapsed variable as restructuring and the absence of working memory capacity as a significant influence on performance.

STUDENTS' COGNITIVE LEVEL AND LABORATORY EXPERIENCE IN BIOLOGY

Reuven Lazarowitz
Technion
Haifa, 32000 Israel

Shulamit Witenoff
Comprehensive High School
K. Tivon, Israel

Science curricula on the secondary school level have been found to require formal operational reasoning. This study was designed to investigate the effect of adapting 9th-grade biology laboratory exercises on the academic achievement of students who had been initially assessed as concrete and transitional operational reasoners by the use of a "Paper and Pencil" Group Instrument testing the logic of ratios and proportions. The research sample consisted of 120 9th-grade students enrolled in a junior high school located in a suburban community in the north of Israel. The four classes chosen for the sample had been streamed academically into two upper and two lower levels. The experimental group consisted of one upper and one lower-streamed class. This same design was used for the control group.

Sixty-one students were exposed to four newly-adapted laboratory exercises on the subject of the pH scale and its relationship to cellular processes. These laboratory exercises were based on an analysis of the cognitive demands of the biology text in present use in Israel (Unity-BSCS) on the subject of the pH scale and its investigation in the laboratory. The new laboratory exercises were then adapted to the special characteristics that concrete and transitional reasoners face when dealing with scientific concepts that require formal operational reasoning. Fifty-nine students continued to use the above-mentioned text, performing the laboratory exercises in it on the subject of the pH scale.

Academic achievement was assessed by a multiple choice questionnaire. Data were analyzed by t-test, analysis of covariance, and multiple regression analysis. Results show that the lower stream experimental class achieved significantly higher, while upper stream experimental experimental and control groups did not differ in their achievement.

Student cognitive level was positively associated with overall achievement scores. The analysis of covariance showed that the major factors that contributed to student achievement on the post-test were in the following rank order, the stream, the instructional materials and procedure, the pre-test, the Piagetian level. Differences also were found to be related to gender.

The positive performance of concrete and transitional students and the girls in the lower stream experimental class on the post-test may be attributed to the characteristics of the "programmed discovery" laboratory work sheets that were developed in this study.

THE RELATIONSHIP BETWEEN CONTRASTING ADVANCE ORGANIZERS AND ACHIEVEMENT OF STUDENTS WITH DIFFERENT SENSORY MODALITY PREFERENCES AND APTITUDE IN A HIGH SCHOOL BIOLOGY LABORATORY

Robert H. Barron
Habersham High School
Cornelia, GA 30531

David P. Butts
The University of Georgia
Athens, GA 30602

This study was designed to examine the relationship between contrasting advance organizers and achievement of students in a secondary biology laboratory. In addition to looking at the influence of the students' sensory modality preference, their aptitude was a dependent variable in the study.

One hundred twenty-six tenth-grade students enrolled in five intact biology classes were the sample for the study. The treatments consisted of four groups -- mixed modality (visual/auditory/kinesthetic) advance organizer, visual/kinesthetic advance organizer, auditory/kinesthetic advance organizer and no advance organizer. Achievement was measured at the conclusion of each specific topic. The treatment period lasted five weeks and was centered on the dissection of laboratory animals typically studied in high school biology classes.

Analysis of covariance procedures were used to analyze the data. Where a multiple comparison procedure was required, the Scheffe' procedure was employed.

The four conclusions of the study were:

1. In a high school biology laboratory, the main effect of contrasting advance organizers on student achievement was significant. The use of advance organizers was associated with higher achievement in 18 of 24 pair-wise contrasts. It is reasonable to conclude that students given advance organizers usually achieve more than those who do not receive advance organizers.
2. No evidence of differences in student achievement due to sensory modality preferences, distinguishable by the student alone, was found.
3. A clear relationship between aptitude and achievement was seen. Students with higher aptitude achieve more,
4. When advance organizers were linked to students' preferred sensory modality, their achievement was higher than when these preferences were not linked.

THE FUNCTIONAL PARADIGMS OF HIGH SCHOOL BIOLOGY TEACHERS

Warren Tomkiewicz
University of Maine
Orono, ME 04469

Gerald Abegg
Boston University
Boston, MA 02215

The purpose of this investigation was to describe and interpret the nature of the functional paradigms of biology teachers based on the four commonplaces of educating (teaching, learning, curriculum, and governance). The concept of a functional paradigm has been supported by Crocker and others as a means of investigating why teachers and classrooms function as they do. Teachers are considered as similar to other communities of scholars in sharing common beliefs, exemplars, etc., which constitute a functional paradigm. In this way, commonalities among teachers rather than differences are recognized. The teaching of human genetics is used as the contextual framework to discuss the functional paradigms because of the underlying biosocial issues involved with this subject. Twenty-eight experienced high school biology teachers recognized for their exemplary teaching and professional involvement participated in this study. Both qualitative and quantitative strategies were employed in the collection of data sources. Modified clinical interviews, field notes, and the administration of a Professional Background Survey; Teaching Strategy Survey, Perception of Student, Curriculum; and Teaching Environment Inventory, the Science Attitude Inventory; and the Science Process Inventory were used to provide a framework for a systematic description and interpretation of the functional paradigms.

Analysis of the data sources provided evidence for patterns in the assertions forming the functional paradigms. Discussion focuses on interpretations that include (1) Teacher paradigms: a) Develop and foster in students a commitment to learning and the process of how to think and learn by providing episodes of problem-solving and decision-making activities; b) Create an atmosphere where expression of ideas and feelings could occur; c) Teachers have a natural curiosity to learn and teach about human-oriented issues and a willingness to share this with colleagues and students. (2) Curriculum paradigms: a) Genetics issues should be a theme throughout the biology curriculum; b) Teachers and students should understand the nature and philosophy of science and the interdisciplinary nature of the curriculum; c) Important human genetics topics suggested by BSCS and the March of Dimes were discussed in class. (3) Student paradigms: a) The controversial nature of human genetics is responsible for the high degree of student interest; b) This interest allows for an understanding about themselves and leads to greater self-confidence; c) Students are better able to deal with misinformation and misconceptions. (4) Governance paradigms: a) The rationale for teaching human genetics was important in order to develop literate, functioning adults; b) Students develop an understanding of the goals, rights, and duties of an adult along with respect for others, and the humanistic qualities to be a thinking citizen; c) The teachers considered autonomy as crucial in the development and implementation of the science and biology curriculum. Additional paradigms are considered for each of the commonplaces.

THE EFFECT OF TEACHERS' LANGUAGE ON STUDENTS' CONCEPTIONS OF THE NATURE OF SCIENCE

Dana Lewis Zeidler
Delaware State College
Dover, DE 19901

Norman G. Lederman
Oregon State University
Corvallis, OR 97330

Conveying an adequate conception of the nature of science to students is implicit in the broader context of what has come to be known as scientific literacy. However, it has previously been demonstrated that possession of valid conceptions of the nature of science and conveyance of those conceptions through ordinary discourse in the presentation of subject matter do not necessarily coincide. The present study examines the possibility that the language teachers use to communicate science content may provide the context (Realist or Instrumental orientations) in which students come to formulate a world view of science. Eighteen high school biology teachers and one randomly selected class from each (n = 409 students) were administered pre and post tests at the beginning and end of the fall term using the Nature of Scientific Knowledge Scale (NSKS). Composite scores of the student changes on the Testable, Developmental and Creative subscales were used to compare those six classes that exhibited the greatest change with those six classes that had the least change on the NSKS. Intensive qualitative observations were also conducted on each teacher over the fall semester which resulted in complete transcripts of teacher-student interactions. Qualitative comparisons of classes with respect to three "clusters" of variables were conducted and subjected to statistical nonparametric tests to determine if they differentiate teachers' language and actions in the presentation of subject matter. These variables represent different contexts (Realist-Instrumental) teachers may use to express themselves and scientific information and concepts. Determining to what extent teachers' language may have impact on changes in students' conception of the nature of science has dirrect bearing on all science teacher preparation programs.

ANALYSIS OF THE EDUCATIONAL IMPLICATIONS OF THE CONCEPT OF SCIENTIFIC REVOLUTIONS

J. Preston Prather
University of Tennessee at Martin
Martin, TN 38237

The work of Thomas Kuhn, a physicist turned philosopher and historian of science, has been a pivotal factor in the growing concern that the picture of science presented in the typical school or college classroom may be incompatible with either the nature of science or society's educational needs. In The Structure of Scientific Revolutions, he posited a revolutionary new concept of the nature and history of science and strongly criticized the current textbook tradition of science education. From the history of science, Kuhn distinguished a genetic dichotomy in scientific development which he described as "normal" scientific activity punctuated by relatively brief episodes of "revolutionary," or abnormal, scientific activity. Normal scientific development generally prevails, he concluded; but revolutionary episodes of noncumulative developmental activity, during which the normal research tradition may be displaced by an incompatible new one, also characterize the history of science. However, he charged, science textbooks typically depict these revolutionary developments as cumulative additions to scientific knowledge.

Most science students therefore receive a tradition-bound, positivistic, perspective of science as a routine, accretionary enterprise, Kuhn declared; but, he contended, this sort of science never existed. Because science textbooks are perceived as authoritative sources of scientific information by scientists and laymen alike, he conjectured, the cumulative effect of the ahistorical textbook tradition is compounded among succeeding generations of science students. On that basis, he decried the dominance of the textbook in science teaching.

Structure has drastically altered the way the nature and development of science is perceived by the scientific community, and it clearly challenged a fundamental dimension of the science curriculum. This study analyzed Kunhn's concept of science, examined his criticism of science teaching, and synthesized the responses of some of his critics for speculative insight into related issues of curriculum development, student attitudes toward science, and teacher training.

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